EVALUATION OF MAIZE (*Zea mays* L.) BASED INTERCROPPING SYSTEMS AS INFLUENCED BY PLANTING GEOMETRY AND WEED MANAGEMENT PRACTICES UNDER RAINFED CONDITION

Thesis

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in

AGRONOMY

by

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CERTIFICATE – I

This is to certify that the thesis entitled **"Evaluation of Maize (Zea *mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Agronomy is the record of research work carried out by **Mr. Chongtham Roben Singh** Registration No.856/2020 under my personal supervision and guidance.

The result of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRONOMY

This is to certify that the thesis entitled **“**Evaluation of Maize (Zea *mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition**.”** submitted by Mr. Chongtham Roben Singh, Admission No. 192/15 Registration No. 856/2020 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (AGRICULTURE) in Agronomy has been examined by the Advisory Board and External examiner on ……………….............

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DECLARATION

I, Mr. **Chongtham Roben Singh**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agronomy.

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Dated:

Place : (Chongtham Roben Singh)

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LIST OF ABBREVIATIONS

a.i.	Active ingredient
ANOVA	Analysis of variance
ATER	Area time equivalent ratio
@	At the rate of
B:C	Benefit cost ratio
C.D.	Critical difference
CR	Competitive ratio
cm	Centimetre
DAS	Days after sowing
^{0}C	Degree Celsius
DF	Degree of freedom
^{0}	Degree
E.C.	Emulsifiable concentrate
et al.	And others
Etc.	Et cetera
Fb	Followed by
Fig.	Figure
g	Gram
>	Greater than
ha^{-1}	Per Hectare
Hrs	Hours
HW	Hand weeding
i. e	Id est (in other words)
kg	Kilogram
LAI	Leaf area index
LER	Land equivalent ratio
<	Less than
^{0}N	North

no.	Number
Max.	Maximum
Min	Minimum
m^2	Square metre
ml	Mililitre
MEY	Maize equivalent yield
mm	Milimetre
M.S.S	Mean sum of square
N	Nitrogen
NS	Not Significant
OC	Organic carbon
pH	Negative log of H ion activity
P.E.	Pre-emergence
PSB	Phosphate solubilizing bacteria
q	Quintal
RBD	Randomised Block Design
RCC	Relative crowding coefficient
RVT	Relative Value Total
₹	Rupees
SEm±	Sum error of mean
S	Significant
S.S	Sum of square
Viz.	Namely

INTRODUCTION

Intercropping was defined as an agricultural practice of cultivating two or more crops in the same space at the same time (Andrew and Kassam, 1976). In intercropping system, all the environmental resources were utilized to maximize crop productivity. This agro-technique was practiced in past decades and achieved the goal of agricultural production. Many scientists worked on intercropping mostly focusing on cereal based intercropping and also proved the success of intercropping (Yildirim and Guvenc, 2005; John and Mini, 2005; Suresha *et al*., 2007; Hugar and Palled; 2008 Seran and Jeyakumaran, 2009; Brintha and Seran, 2009). It was more advantageous when legume was included as one of the components of intercropping as it gave higher yield; greater land use efficiency per unit area and at the same time enhanced soil fertility through fixation of atmospheric nitrogen and provided complimentary benefit to the companion crop (Willey, 1979). According to Ghosh (2004), spatial arrangements of plants, planting rates and maturity dates should be considered when planning intercropping because they were some of the most important factors for better yield advantage.

Cereal + legume was the most popular intercropping system in the tropics (Snaydon and Harris, 1979). Intercropping of maize with legume could reduce the amount of nutrients uptake by main crop from the soil as compared to maize monocrop. During the absence of nitrogen fertilizer, intercropped legumes would fix nitrogen from the atmosphere and would not compete with maize for nitrogen (Adu-Gyamfi *et al*., 2007). The mixture of nitrogen fixing crop and non fixing crop gave greater productivity than monocropping (Seran and Brintha, 2009). Intercropping of cereal with legume was a recognized practice for economizing the use of nitrogenous fertilizer and increasing the productivity and profitability per unit area and time. One of the main reasons for higher yield in intercropping was that the component crops were able to use growth resources differently and make better use of natural resources than grown separately (Willey, 1979). Intercropping of cereal with legume was popular in rainfed areas (Dhima *et al.*, 2007) due to its advantages for soil moisture conservation and weed control. Maize + legume intercropping system, besides increasing productivity and profitability, also improved soil health, conserved soil moisture and increased total production (Padhi and Panigrahi, 2006; Singh *et al.*, 2008).

Crop weed competition was one of the major constraints in productivity of any crop and as such it interfered the successful crop production. In India, it was observed that weeds caused 45 percent loss of agricultural production (Gupta and Anmol, 1997).The critical period of crop weed competition was the period from the time of sowing upto which the crop was to maintained in a weed free environment to get higher yield. Cereal + legume intercropping was an important way to control weeds, increase yield, and also to reduce the use of herbicides. Weeds caused severe yield reduction in maize production and losses went upto 40-60 percent (Ayeni *et al.*, 1984). However, cereal + legume intercropping reduced weed occurrence and increased maize production (Zuofa *et al.,* 1992). In India, the presence of weeds, in general reduced the maize yield by 27-60 percent depending upon the growth and persistence of weed population in maize crop (Sunitha *et al*., 2010; Jat *et al*., 2012; Singh *et al*., 2015; Kumar *et al.,* 2013). Weed management in intercropping system needed concentrated scientific efforts to provide weed free environment to both crop components. Wider row spacing in maize could be used to grow short duration legumes which would not only act as smoother crop but also would give additional yield. Weed management approach involving intercropping, herbicides and non- chemical methods in maize and maize based intercropping system was very important to provide effective and acceptable weed control for realizing high production (Shah *et al*., 2011).

Soil health improvement, moisture conservation and weed management were considered as important factors in cereal + legume intercropping systems for increasing productivity under rainfed agriculture. Hence, search for suitable cereal + legume intercropping system in rainfed agriculture became the need of the hour under the agro-physiographical conditions of N.E.H. region particularly of Nagaland. Among the cereal crops, maize was considered to be a very important cereal crop in India particularly in N.E.H. Region where animal was one of the important components in rainfed agriculture. Among the *kharif* legumes, the promising legume crops which might be used in maize + legume intercropping under rainfed agriculture of Nagaland were black gram and soybean.

The present studies was, therefore, proposed with the hypothesis that planting geometry and weed management practices in maize + legume intercropping systems had no influence on plant growth and yield parameters, weed control, economic return and soil health under rainfed conditions. Hence, the present studies were taken up with the following objectives:

1. To study the effect of planting geometry and weed management practices in maize + legume intercropping systems.
2. To study the effect of maize + legume intercropping systems on soil health.
3. To study the economics of maize + legume intercropping systems.

REVIEW OF LITERATURE

An attempt has been made to review the available literatures on the effect of planting geometry, weed management and their interactions in maize based intercropping systems in regards to crop production, productivity, soil health and economics of maize intercropping with legume crops *viz*., black gram and soybean. Although the major emphasis was given on the works pertaining to maize, black gram and soybean; works on other crops were also reviewed wherever found appropriate. The literature review on these aspects are presented under following heads:

2.1 Intercropping and crop production

Intercropping was defined as the growing of two or more crops simultaneously on the same field (Andrew and Kassam, 1976). Sullivan (2003) also defined intercropping as a practice of growing two or more crops in the same field at the same time. The interest of growing two or more crops at the same time on the same piece of land was increased because of the potential increase in area productivity (Fortin and Pierce, 1996).

Intercropping was the practical application of basic ecological principles, *viz.,* diversity, competition, and facilitation for crop production (Gomes and Gomez, 1983). In recent years, intercropping has been widely used as one of the techniques for increasing crop yields in different land forms (Li *et al.*, 1999). One of the main reasons for higher yield in intercropping was that the component crops were able to use growth resources differently, so that when grown together, they complemented each other and make better overall use of growth resources than grown separately (Willey, 1979).

Ghanbari *et al*. (2010) and Zhang *et al*. (2011) reported that intercropping system utilized resources like water, soil, nutrients, light, etc. more efficiently and as a result, their productivity was increased. Banik *et al*. (2006) also reported that a mixture of two or more crops would often give a better coverage of soil and reduced the growth of weeds, runoff loss of soil and nutrients. Intercropping generated beneficial biological interactions between crops, increased grain yield and stability, more efficient use of available resources and reduced weed pressure (Kadziuliene *et al.*, 2009).

Yildirim and Guvenc (2005) and Matusso *et al*. (2014a) opined that intercropping could significantly be increased the total productivity as compared to sole cropping due to better utilization of water, nutrients and solar energy. Agricultural sustainability encouraged the intercropping practices because they could improve soil conservation and soil fertility, had more stable yield and potential for pest and disease control (Guvenc and Yildirim, 2006). Sharaiha and Ziadat (2007) also reported intercropping systems as one of the agricultural practices to control soil erosion.

Intercropping systems could cause more effective use of resources by providing symbiotic nitrogen from legumes, or making available inorganic phosphorus fixed in soil because of lowering of pH via nitrogen fixing legumes (Jensen, 1996; Aminifar and Ghanbari, 2014). Zhou *et al*. (2000) suggested that intercropping could enhance nitrogen utilization. Nitrogen fixation by a legume crop could be the cheapest and easiest way for supplying nitrogen to the non-legume in intercropping systems. Karlidag and Yildirim (2009) reported that legume plants might provide biologically fixed nitrogen to the non-legumes. Moreover, intercropping systems could reduce the nitrate leaching from the soil profile since intercropping systems utilized soil nutrient elements more efficiently than pure stands (Zhang and Li, 2003). Whitmore and Schröder (2007) concluded that the yield and profitability of intercropping systems could be correlated to the residual nitrate at harvest and intercropping systems could also be used to reduce nutrient pollution in agricultural practices.

Intercropping practices had complementary effect for plants in regard to resources use, which effectively utilized solar radiation, water and nutrient elements as compared to pure cropping (Eskandari, 2011). The successful intercropping applications improved to partake the available resources over time and space using the differences between crops used in intercropping in terms of canopy growth rate, canopy and root structure (Midmore, 1993). Complementary effects of intercrops could be expressed as complementary resource use and niche differentiation in space and time, thus reduced competition between crop species and improved greater acquisition of limiting resources (Li *et al*., 2014).

2.2 Cereal + legume intercropping

According to Willey (1979), advantages of cereal + legume intercropping systems were higher yield, greater land use efficiency and improvement of soil fertility through nitrogen fixation by component legume.

Legume + cereal intercropping, *i.e.* the practice of growing two (or more) crops simultaneously in the same land area, offered a potential method of reducing inputs such as nitrogenous fertilizers (Hauggaard-Nielsen *et al*., 2007). Intercropping positively influenced both crop growth and yield (Bilalis *et al*., 2005). Moreover, weed suppression was noted as one of the advantages of intercropping (Mohler and Liebman, 1987; Liebman and Davis, 2000; Brainard and Bellinder, 2004; Chikoye *et al*., 2004; Fujiyoshi *et al*., 2007; Hauggaard-Nielsen *et al*., 2007; Bilalis *et al*., 2008). Liebman and Dyck (1993) reported a decrease of weed biomass in intercrop as compared to monocrop systems in 47 studies, a higher level of weed biomass in four studies and variable results in another three cases.

Kalra and Gangwar (1980) observed that there was an increase in total grain production from 29.5 to 92.5 percent under maize + legume intercropping system over sole maize.

Srivastava *et al.* (1983) reported that intercropping of maize with legumes increased the combined yield of maize and intercrop.

Chui and Shibles (1984) reported that yield of soybean in maize + soybean intercropping system was 585 kg ha^{-1} as compared to 730 kg ha^{-1} in sole crop of soybean.

Singh and Singh (1984) reported that the grain yield of maize increased by 17-22 percent in an intercropping studies of maize with legumes like soybean and black gram under Tarai conditions. Bhatt and Damor (1985) concluded that legume crops had no adverse effect on maize yield under rainfed condition.

Hefni *et al*. (1984) reported that maize plant height was increased when intercropped with soybean. Mutnal and Hosmani (1985) also reported an increase in height of maize plant due to intercropping with legumes.

Singh *et al.* (1988) advocated that maize intercropped with legumes produced higher number of cobs per plant and less barrenness when compared to maize in sole stand. Singh *et al.* (1988) also reported that maize intercropped with black gram increased cob number, grains per cob and 100-grain weight than sole crop. Similarly, Ibrahim *et al*. (1990) observed significant increase in yield components of maize due to intercropping with cowpea.

Venkatachalam (1990) observed that maize intercropped with legumes like greengram and cowpea recorded higher plant height over maize and soybean intercropping system.

Chatterjee and Mandal (1992) reported that intercropping especially cereal + legume combination could increase production and productivity by better utilization of resources and thereby minimized the risks and brought stability under rainfed conditions.

West and Griffith (1992) observed that maize yield was increased by 26 percent in maize + soybean strip intercropping.

Abbas *et al.* (1995) observed that the height of maize increased significantly in maize + pigeon pea (4:2 and 2:2) as compared to sole crop of maize due to dominant nature of the latter in the combination.

Prasad and Rafey (1996) noticed that intercropping of maize with soybean, (1:1 and 1:2) under rainfed conditions effectively reduced the weed density and dry weight of weeds at 30 and 60 days after sowing as compared to the pure crops.

Pandita *et al.* (1998) reported that row ratio of 1:2 (maize + frenchbean) attained maximum grain yield. Maize equivalent (7.88 t ha^{-1}) and land equivalent ratio (1.61) also revealed that association of frenchbean with maize crops improved availability of residual nitrogen in the soil and proved profitable with the highest benefit ratio (1:87).

Shivay *et al.* (1999) reported that maize grain yield was significantly influenced by different cropping systems in both the years (1993 and 1994) of experimentation. Intercropping of maize with black gram significantly increased the grain yield of maize as compared to sole maize grown both in normal row planting and paired row planting. However, it was statistically at par with that of maize + soybean cropping system.

Analysis of numerous cereal and legume crops revealed that maize and soybean were the best partners under intercropping because both crops had complementary characteristics (Kocsy *et al*., 2001).

Singh and Singh (2001) revealed that among the different cropping systems of maize and soybean, paired row of maize + 2 rows of soybean gave the highest value of total yield and net return.

Shekhawat *et al*. (2002) reported that planting in 2:2 rows of maize + black gram intercropping proved to be superior in all observations recorded over 1:1 row planting system.

Bhuvaneshwari *et al*. (2002) reported reduction in weed dry matter by intercropping maize with cowpea and soybean in Tamil Nadu.

Kumar *et al*. (2003) reported that weed growth was significantly lower under intercropping of maize with soybean than sole crop of maize. The yield and economic advantage were higher with 1:1 row ratio followed by 1:2 row ratio, and 1:3 row ratio.

Lal (2003) reported that maize + soybean intercropping increased the efficiency of land use through improved soil productivity, maintained a sustainable yield over the year and increased the total crop yield per unit area over sole crop through better use of resources by the components.

Tsubo *et al*. (2005) observed that maize intercrop with legume were able to reduce the amount of nutrients taken from the soil as compared to maize monocrop.

Hugar and Palled (2008) focused intercropping on the cereal based intercropping and proved the success of intercropping.

Banik and Sharma (2009) reported that cereal + legume intercropping systems were superior to monocropping as found in maize + bean intercropping.

Kithan and Longkumer (2014) conducted an experiment to study the performance of maize + soybean intercropping system on yield and economics. They suggested that the paired rows of maize + soybean (2:2) was found to be the best combination and recorded the maximum LER, grain yield and net return.

Cui *et al*. (2017) reported that different row ratio planting patterns significantly affected the grain yield of intercrops in the maize + soybean relay strip intercropping system.

2.3 Planting geometry of cereal + legume intercropping and its effects on weed management and productivity

Tripathi (1981) reported that soybean as an intercrop in maize either one row or two rows in between 2 maize rows significantly reduced the weed density and dry weight of weed thus reduced crop weed competition. Tripathi and Singh (1983) further reported that growing one or two rows of soybean (*Glycine max* L.) as an intercrop in maize, reduced weed numbers and weight significantly and increased maize yield.

Steiner (1984) reported weed suppression in maize + groundnut intercropping. Mugabe *et al*. (1982) noted that intercropping controlled weed effectively and reduced the harvestable biomass. Makindea *et al*. (2009) found that leafy greens could be intercropped with maize to control weeds in the tropics and increase productivity.

Arya and Saini (1989) observed a significant effect of crop geometry on the grain yield of maize. They recorded the highest grain yield of maize (2200 kg ha^{-1}) when maize and soybean were planted at 45/30 cm in 2:2 rows.

Thattil *et al.* (1991) reported that due to its superior height, maize was dominant over mung beans. The dominant effect of maize increased with increasing densities. Intra-row spacing of both crops significantly affected the intercrop yield.

Kumar and Singh (1992) also observed *Cyperus rotundus*, *Echinochloa colonum*, *Brachiaria ramose* and *Commelina benghalensis, Cynodon dactylon, Sorghum haleplense* as the dominant weed flora in maize + legume intercropping system. The weed growth was significantly lower under intercropping of maize with soybean than the sole crop of maize. Reduction in grain yield of maize and soybean was 13-15 percent and 47-55 percent, respectively under intercropping. Kithan and Longkumer (2014) observed *Aamaranthus viridis* (L.), *Leucas aspera*, *Cyperus rotundus* (L.), *Cyperrus iria* (L.), *Cynodon dactylon* (L.), *Mimosa pudica* (L.), *Setaria glauca* (L.), *Borreria hispidia* (L.), *Imperata cylindrical* (L.) and *Digitaria sanguinalis* (L.) as the dominant weed flora in maize + soybean intercropping system.

Thakur (1994) revealed that maize + soybean intercropping system significantly reduced the density of weeds as compared to black gram as a component crop with maize.

Prasad and Rafey (1996) stated that intercropping of maize with soybean, irrespective of their row ratios (1:1 and 1:2) effectively reduced the weed density and dry weight of weeds at 30 and 60 days after sowing as compared with their pure crops.

Harvey *et al*. (1997) reported that it was logical to expect that weed management should improve if the row spacing of corn was narrow.These results supported the results of many researchers that plant population per unit area and herbicide used in corn increased the maize yield.

Pandey *et al.* (2002) noticed that all the weed control treatments effectively controlled the weeds and produced significantly higher yield of maize and soybean. However, row of soybean in between two rows of maize provided significant yield of maize.

Pandey and Prakash (2002) reported that maize and legume intercropped either as paired rows + two rows of legume or one row of legume in between two rows of maize adversely affected the weed growth and caused 22.4 percent and 31.9 percent weed growth suppression as compared with sole maize respectively. However, planting geometry alone was not sufficient to overpower weeds during *kharif* season because rains provided a congenial environment for weeds.

Kumar *et al*. (2003) observed that among different intercropping treatments, intercropping of maize + soybean with 1:2 and 1:3 row ratio at different population density recorded significantly lower weed dry matter than that of 1: I row ratio either at 100 : 100 or 100 : 50 at 30 days after sowing and intercropping of maize and soybean in 1:1 row ratio at 100:50 population ratio recorded significantly higher grain yield of maize (2839 kg ha^{-1}).

Singh *et al*. (2005) reported that different planting patterns and sole soybean proved significantly superior over sole maize in reducing weed density and dry matter at 50 DAS. Paired planting of maize and soybean (2:2) and sole soybean were more effective in controlling weeds than alternate planting of maize + soybean (1:1).

Kumar and Thakur (2005) reported that maize intercropped with soybean and black gram had no significant variations on weed density and weed dry matter accumulation but caused 18.4 percent and 13.2 percent reduction in weed density respectively. Singh *et al*. (2005) concluded that maize + soybean (1:1 or 1:2) was found effective for controlling weeds in maize.

Black gram intercropped with maize as smoother crop suppressed the weed growth to the extent of 28.3 percent (Tripathi *et al*., 2005). Maize + soybean (1:1) suppressed the weed species by canopy cover which resulted in the highest weed smoothering efficiency as compared to maize + greengram (Shah *et al*., 2011). Maize + black gram (1:1) was effective in controlling weeds and resulted in higher grain yield as compared to maize + black gram (2:1) and maize + black gram (2:2) at Raipur, Chhattisgarh (Sanjay *et al*., 2012).

Intercropping proved its benefits to control weed in crop production by reduced growth and development of weed (Liebman and Dyck, 1993; Poggio, 2005; Sharma and Banik, 2013). In a maize + soybean intercropping experiment, Shah *et al*. (2011) showed a significant decrease of weed dry matter under intercropping conditions as compared to sole crop. Since weed growth was suppressed by intercropping, it allowed reducing the dependency on herbicide in crop production (Carruthers *et al*., 1998, 2000; Banik *et al*., 2006). Although intercropping reduced weed growth, additional weeding was necessary to control weeds efficiently and to ensure high yield of crops (Moody, 1977; Carruthers *et al*., 1998; Shetty and Rao, 1981). Khan *et al*. (2012) indicated that the combination of hand weeding and maize + soybean intercropping were more effective in terms of weed suppression and enhanced yield of maize.

Bilalis *et al*. (2010) concluded that sowing two rows of soybean was more effective than one row with maize at a constant sowing density in controlling weed population.

Shah *et al*. (2011) reported that weed dry weight recorded at all stages of crop growth were significantly influenced by different intercropping systems of maize with soybean and greengram.

Dwivedi and Shrivastava (2011) reported that at important growth stages of crop *i.e.* 50 and 75 DAS, the maximum reduction in number of total weeds were found with maize + black gram (1:1) intercropping system.

Choudhary *et al*. (2013) found that minimum weed count and weed dry matter were recorded in pop corn + soybean 2:2 intercropping.

Patel *et al*. (2015a) reported that intercropping of maize with cowpea, soybean, black gram or greengram effectively reduced the population and dry weight of weeds as compared to sole crop of maize.

Kithan and Longkumar (2016) reported the lowest weed population in 2:2 paired row ratios of maize + soybean.

Haque *et al*. (2016) clearly revealed from the investigation that intercropping of maize either with soybean or groundnut (1:2) markedly reduced the weed density and dry weight, thereby increased weed control efficiency, but these could not affect the growth and yield attributes.

2.4 Effect of weed management on maize + legume intercropping and sole crop

2.4.1 Chemical weed management with Pendimethalin

a) Maize and legume intercropping

Thakur (1994) reported that application of pendimethalin 1.5 kg ha^{-1} in maize + legume intercropping system reduced the weed population from 509 m^{-2} in weedy check to 283 m^{-2}. Similarly, reduction in weed dry matter was from 70.1 q ha^{-1} in weedy check to 28.3 q ha^{-1} with weed control efficiency of 59.6 percent. Correspondingly, the grain yield of maize increased by 108.4 percent over weedy check (11.9 q ha^{-1}). Prasad and Rafey (1996) also reported that pre-emergence application of pendimethalin 1.0 kg ha^{-1} was found comparable with two hand weeding (30 and 60 DAS) and significantly superior over control in reducing weed population and increasing grain yield. Sharma (1998) found that application of pendimethalin 0.75 kg ha^{-1} as pre-emergence in maize based intercropping system significantly reduced weed dry matter by 69.5, 144.7 and 1527 g m^{-2} at 30, 60 DAS and at harvest respectively as compared to weedy check (114.4, 219.8 and 2259.7 g m^{-2}, respectively) which resulted in enhanced maize grain yield by 64.2 percent over weedy check (31.39 q ha^{-1}).

Prasad (1995) stated that combination of pigeon pea + maize intercropping with pendimethalin at 1.0 kg ha^{-1} gave the highest pigeon pea equivalent yield with better weed control.

Jat and Gaur (2000) reported that the highest NPK uptake in maize + soybean intercropping system was observed in pre-emergence application of pendimethalin at 1.0 kg ha^{-1}.

Pandey and Prakash (2002) observed that alachlor (2.0 kg ha^{-1}) as pre-emergence weedicide was superior over pendimethalin (1.5 kg ha^{-1}) pre-emergence application in maize and soybean intercropping system.

Deshveer and Singh (2002) revealed that pre-emergence application of pendimethalin at 1.0 kg ha^{-1} resulted a significant reduction in weed density and biomass in maize based intercropping.

Pandey and Prakash (2002) observed a significant reduction in weed density and dry matter when pre-emergence application of pendimethalin (1.5 kg ha^{-1}) was made in maize + soybean intercropping system. Corresponding increase in grain yield were 265.7 and 362.7 percent over weedy check 557 kg ha^{-1} and 387 kg ha^{-1}.

Singh *et al*. (2005) reported that weed management practices significantly reduced the density and dry weight of weeds at 50 DAS over weedy check. Among weed management practices, a combination of alachor along with hoeing proved to be the most effective in control of monocots as well as total weeds. However, dicot weeds were effectively controlled by pendimethalin along with hoeing.

Patel *et al*. (2006) reported that pre-emergence application of pendimethalin 0.25 kg ha^{-1} either with atrazine or alachlor or metolachlor each with 0.5 kg ha^{-1} or metribuzin 0.15 kg ha^{-1} recorded significantly lower density of monocot and dicot weeds at all intervals and recorded higher grain yield of maize as compared to all other treatments.

Ameta *et al*. (2008) reported that maize and soybean intercrop in paired rows in a 2:2 row ratio (30/90) treated with PE pendimethalin @1.0 kg ha^{-1} produced a significant reduction in weed count which in turn resulted in the least weed dry matter.

Rajeshkumar *et al*. (2017) from his experimental results concluded that, the pre emergence application of pendimethalin @ 0.75 kg ha^{-1} followed by rotary hoeing at 35 DAS recorded lesser weed density, dry weight, higher weed control efficiency and produced the higher yield attributes and grain yield of maize under maize based cowpea intercropping.

Rahimi *et al*. (2017) reported that among the weed management practices, pendimethalin 0.75 kg ha^{-1} as PE 3 DAS + one HW (hand weeding) 25 DAS favourably increased the growth, yield attributes and grain yield of maize under maize based black gram intercropping.

b) Maize

Prasad and Rafey (1996) reported that pre-emergence application of pendimethalin @ 1.5 kg a.i.ha^{-1} proved to be at par with two hand weeding (30 and 60 DAS) in reducing weed population in rabi maize on sandy loam soils of North Bihar. Kumar and Reddy (2000) also found that pre-emergence application of pendimethalin @ 1 kg a.i.ha^{-1} with four hand weeding was effective in controlling weeds over weedy check in maize.

Patel *et al.* (2006) reported that pre-emergence application of pendimethalin at 0.5 kg ha^{-1} with atrazine at 0.5 kg ha^{-1} gave significantly lower density of monocot and dicot weeds at all the intervals and also recorded higher grain yield of maize as compared to all other treatments.

Dubey (2008) found that application of pendimethalin 1.0 kg ha^{-1} along with one HW at 30 DAS significantly reduced the density of weeds than weedy check.

Singh *et al*. (2015) reported that the lowest weed density (49.5 m^{2}) was recorded with pendimethalin (1000 g) + 1 HW which was statistically similar to pendimethalin (500g) + atrazine (500 g) and both were significantly superior to weedy check.

c) Black gram

Ramanathan and Chandrashekharan (1998) reported that application of pendimethalin as pre emergence @1.5 kg ha^{-1} along with hand weeding at 30 DAS observed maximum weed control efficiency and it led to increase the productivity of black gram. Sharma and Rajkhowa (1988) found that pendimethalin 1 kg ha^{-1} was quite effective for the control of grasses and sedges in black gram. Similarly, Rathi *et al*. (2004) concluded that low dose of pendimethalin (0.5 kg ha^{-1}) followed by one hand weeding at 60 DAS significantly reduced the weed growth and gave higher grain yield of black gram. Raman *et al*. (2005) observed that pendimethalin at 1.0 kg ha^{-1} was the next best only after hand weeding twice (20 & 40 DAS) in influencing weed biomass and weed count in black gram.

Bhandari *et al*. (2004) reported that high doses of pendimethalin significantly reduced weed population and dry matter of weeds in black gram.

Kumar and Tewari (2004) reported that application of pendimethalin (1.0 kg ha^{-1}) as pre-emergence followed by fluazifop-p-butyl (0.375 kg ha^{-1}) as post-emergence caused complete mortality of *Trianthema monogyna*, a major broad-leaved weed and *Sorghum halepense*, a perennial grass in summer black gram.

Kumar *et al*. (2006) reported that pendimethalin at 0.75 kg ha^{-1} in integration with one hand weeding (45 DAS) resulted in minimum weed number and dry matter accumulation and had significantly higher seed yield of black gram. They also reported that unchecked growth of weeds on an average caused 48.1 percent reduction in the seed yield of black gram.

Patel *et al*. (2011) also reported the highest seed and haulm yield as influenced by pendimethalin at 0.75 kg ha^{-1} as pre emergence application along with one hand weeding at 40 DAS in summer black gram.

Khot *et al*. (2012) reported that pre-emergence application of pendimethalin 1 kg ha^{-1} + hand weeding + IC (intercultivation) at 40 DAS was effective in reducing weed population in summer black gram.

Kavita *et al*. (2014) observed superiority of pendimethalin (1.0 & 1.5 kg ha^{-1}) over imazethapyr (50 & 75 g ha^{-1} applied pre-emergence). Imazethapyr at 75 g ha^{-1} (PRE) yielded at par with hand weeding twice, pendimethalin (1.0 & 1.5 kg ha^{-1}) and fenoxaprop-p-ethyl POE at 125 g ha^{-1}.

Bhowmick *et al.* (2015) reported that pre-emergence application of pendimethalin either at lower dosage of 0.75 kg ha^{-1} along with one hand weeding at 40 DAS or at higher dosage (1.0 kg ha^{-1}) alone, besides using normal seed rate (22.0 kg ha^{-1}) might be a good weed management practice for maximizing productivity of *Kharif* black gram in West Bengal.

Raju *et al*. (2017) reported that application of pendimethalin 30 percent EC 0.75 kg a.i.ha^{-1} PE fb imazethapyr 75 g a.i.ha^{-1} or quizalofop-p-ethyl 75 g a.i.ha^{-1} at 20 DAS was effective for controlling weeds, obtaining higher seed yield, net returns and B:C ratio in black gram under rainfed conditions of Karnataka.

d) Soybean

Porwal *et al*. (1990) reported that application of pendimethalin 1.25 kg ha^{-1} in soybean crop significantly reduced the weed biomass and increased crop yield over the control. Veeramani *et al*. (2000) also reported that application of pendimathalin at 0.75 kg ha^{-1} + hand weeding at 40 DAS had significantly higher soybean seed production and significantly lower weed population over the control.

Shah *et al*. (2000) found that pendimethalin gave significantly higher soybean yield (1639 kg ha^{-1}) than other treatments. Pendimethalin was also found effective in controlling weeds in spring soybean.

Gurjar *et al*. (2001) reported that application of pendimethalin (1.0 and 1.5 kg ha^{-1}) gave significantly higher yield attributing characters and grain yield of soybean. Singh (2007) also reported that pre-emergence pendimethalin 0.45 kg ha^{-1} + hand weeding 30 DAS control weeds effectively and provided high grain yield of soybean.

Peer *et al.* (2013) found that pendimethalin 1.0 kg ha^{-1} integrated with one hand weeding at 35 DAS (critical period of weed removal) was the most appropriate method for effective weed management and profitable cultivation of soybean. Other methods were either less profit earners or labour expensive.

Patil *et al*. (2018) reported that pendimethalin @ 0.750 kg ha^{-1} pre emergence + 1HW and IC at 20 DAS recorded significant reduction in weed dry matter and higher weed control efficiency resulting in higher yield of soybean.

2.4.2 Hand weeding

a) Maize and legume intercropping

Tiwari *et al*. (1987) opined that cowpea as an inter crop in maize was able to control 23 percent of total weeds and thereby one hand weeding could be saved.

Thakur (1994) while working on maize + soybean intercropping system, reported minimum density and dry matter of weeds under twice hand weeding (20 and 40 DAS).

Jat (1996) reported that two hand weeding at 25 and 45 DAS in soybean intercropped with maize showed significant improvement in yield attributes and recorded 49.6 percent higher grain yield of soybean than 5.14 q ha^{-1} obtained in soybean weedy check.

Shekhawat *et al*. (2002) reported that weed free situation in maize + black gram intercropping system improved growth characters, yield attributes and grain yield of maize and black gram.

Chalka (2003) observed a significant reduction in dry weight of weeds with one hand weeding at 30 DAS as compared to control and proved to be better over herbicide treatment either with alachlor or pendimethalin on weed control in maize based intercropping system.

Khan *et al*. (2012) indicated that the combinations of hand weeding in maize + soybean intercropping were more effective in weed suppression and enhanced yield of maize.

Choudhary *et al*. (2013) recorded minimum weed density under farmer's practice (two hoeing 15 and 30 DAS) followed by metribuzin 0.35 kg ha^{-1} + one hoeing 25 DAS at all successive growth stages of pop corn.

Patel *et al*. (2015a) reported that all the weed control treatments resulted in enhancement of maize grain yield and hand weeding gave significantly higher grain yield of maize under maize + legumes intercropping system.

Haque *et al*. (2016) reported that hand weeding thrice at 15, 30 and 45 DAS in maize intercropped with soybean markedly reduced weed density and dry weight. However, manual weeding and pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} proved to be equally effective in increasing growth parameters, yield attributes and yield.

b) Maize

Sharma *et al*. (2000) reported that hoeing at 15 DAS controlled the growth of all weed species and their population and hoeing at 30 DAS controlled less than half (23-32 weeds m^{-2}) as compared with no inter-culture (67-70 weeds m^{-2}). Earthing up at 30 DAS resulted into the virtual elimination of weeds throughout the crop growth period.

Patel *et al*. (2006) reported that twice HW at 20 and 40 DAS and PE application of atrazine @ 0.50 kg a.i.ha^{-1} in combination with pendimethalin @ 0.25 kg a.i.ha^{-1} were found to be superior in weed control and recorded higher grain yield of 3658 and 3652 kg ha^{-1} respectively.

Prasad *et al*. (2008) reported that manual weeding at 15 and 30 DAS recorded the highest WCE (70.90 percent) with grain yield of 32.30 q ha^{-1}.

Sarma and Gautam (2010) found that two HW at 25 and 45 DAS was the best in producing higher yield of maize along with minimum weed density (4.0 percent) and weed dry weight (3.3 percent).

Malviya *et al.* (2012) reported higher grain yield of maize with HW at 20 and 40 DAS and pendimethalin @ 1.0 kg a.i.ha^{-1} as PE *fb* HW at 30 DAS. They were at par with weed free treatment.

Kumar *et al*. (2013) reported that the highest grain yield was recorded in conventional tillage maize with HW at 15 and 30 DAS which was at par with zero-tillage maize where glyphosate was applied as pre-plant incorporation followed by atrazine + halosulfuron @ 1.0 kg a.i.ha^{-1} + 90 a.i. g ha^{-1} as post-emergence (PoE).

Samanth *et al*. (2015) reported maximum grain yield in farmer's practice (HW at 20 and 40 DAS) and atrazine @ 1.0 kg a.i.ha^{-1} as PE fb HW at 30 DAS.

Swetha (2015) reported that HW at 20 and 40 DAS recorded a higher grain yield of 6580 kg ha^{-1} which was at par with topramezone + atrazine @ 25.2 + 250 g a.i.ha^{-1} as PoE (6436 kg ha^{-1}).

Stanzen *et al*. (2016) observed that 2 HW recorded significantly higher number of grains cob^{-1}, 1,000-grain weight and grain yield which was statistically at par with atrazine 1 kg ha^{-1}. They further reported that the minimum density of weeds and biomass was observed under 2 HW which was at par with atrazine 1 kg ha^{-1}.

The maximum grain yield of 8.92 t ha^{-1} and minimum weed density and dry weight of all major weed species were recorded in 2HW at 15 and 30 DAS (Kumar *et al*., 2017).

c) Black gram

Singh and Singh (1990) and De *et al*. (1995) obtained the highest seed yield of black gram with hand weeding twice. Choubey *et al*. (1999) observed that in summer sown black gram, hand weeding once at 30 days after sowing produced the highest grain yield followed by chemical weed control. Similarly, Kumar (2000) reported that in *rabi* season black gram, hand weeding twice was superior over the rest of the herbicides for the control of *Cuscuta*. Srivastva and Srivastva (2002) found that manual weeding at 30 days after sowing was more effective in suppressing the weed density in black gram as compared to pendimethalin and unweeded control. Veeraputhiran (2003) reported that the higher number of pods plant^{-1} and grains pod^{-1} were produced under hand weeding followed by mechanical weeding. The highest grain yield was recorded under hand weeding twice with 30 x 10 cm spacing in black gram.

In black gram, weeds could be controlled by hand weeding (Chand *et al*., 2004). Yadav *et al*. (2015), on the basis of the data of two years experimentation, concluded that weed free (two hand weedings at 20 and 40 DAS) treatment recorded maximum seed yield followed by pre-mix herbicides *i.e*. imazethapyr + imazamox (pre-mix) at 0.05 kg ha^{-1} and pendimethalin + imazethapyr (pre-mix) at 1.0 kg ha^{-1} application. The net return and benefit: cost ratio were the highest in imazethapyr + imazamox (pre-mix) at 0.05 kg ha^{-1} followed by pendimethalin + imazethapyr (pre-mix) at 1.0 kg ha^{-1}.

Weeding twice significantly increased the number of pods plant^{-1}, number of seeds pod^{-1}, seed weight and seed yield in black gram (Vaishya *et al*., 2003; Asaduzzaman *et al*., 2010). Nirala and Dewangan (2012) reported the lowest density and dry matter production of weeds, weed intensity, weed growth rate, relative weed density under hand weeding twice (20 and 40 DAS), followed by imazethapyr at 25 g ha^{-1} (pre) in black gram. Similarly, Vikas *et al.* (2013) obtained the highest seed yield with hand weeding twice (20 and 40 DAS) and the values were found statistically at par with post-emergence application of imazethapyr 25 g ha^{-1} at 20 DAS. Patel *et al*. (2015b) reported that hand weeding twice (20 and 40 DAS) was superior to other treatments in respect of reducing the density and dry weight of weeds and recorded higher seed and haulm yields.

Pongen and Nongmaithem (2017) reported that hand weeding at 25 and 45 DAS gave the maximum decrease in weed density, dry weight of weeds and recorded the highest growth and yield of black gram followed by application of pendimethalin 0.75 kg ha^{-1} *fb* one hand weeding at 25 DAS.

Unchecked weeds have been reported to cause a considerable reduction in the grain yield of black gram in case of summer and *kharif* black gram and the reduction could be as high as 41.2 and 41.6 percent respectively (Singh, 2011). Therefore, removal of weeds at appropriate time using a suitable method was essential to obtain high yields of black gram.

With abundant labour availability, hand weeding at 20 DAS and interculture at 40 DAS may be recommended for obtaining higher yield (1182 and 5873 kg ha^{-1} seed and haulm yield, respectively) and reduced population of weeds *i.e.* 41.33 m^{-2} . With the current trend of increased cost and reduced availability of manpower, pendimethalin followed by quizalofop was the best option available for harvesting higher yield (seed and haulm yield of 1120.6 and 5194.3 kg ha^{-1}) as well as for controlling weeds population *i.e*. 44.00 m^{-2} (Sahoo *et al*., 2017).

d) Soybean

Jain and Tiwari (1992) found that two hand weeding at 30 and 45 DAS gave excellent control of weeds in soybean. Rao *et al*. (1995) reported that a greater yield of soybean (20.5 q ha^{-1}) was obtained when the crop was hand weeded twice (20 and 40 DAS).

Two hand hoeing were recommended for effective weed control in soybean (Jain *et al*., 2000; Rakesh & Shirvastava, 2002; Galal, 2003; Singh & Jolly, 2004).

Ahmed *et al*. (2001) reported that application of two hand hoeing was more effective in suppressing weeds and increasing soybean seed yield.

Pandya *et al*. (2005) also reported high grain yield after two hand weeding and cloazone 1 kg ha^{-1} + hand weeding.

Akter *et al*. (2016) reported that two times hand weeding (20 and 40 DAS) controlled the weeds most effectively and led to the highest seed yield (2.23 t ha^{-1}) which was statistically at par (2.19 t ha^{-1}) with herbicide application.

Paudel *et al.* (2017) concluded that two hand weeding at 20 and 40 DAS reduced weed population and weed dry matter production in soybean and thus recorded higher grain yield. However, from the economic point of view and shortage of labourers during critical period of crop weed competition of soybean, pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-p-ethyl 50 g ha^{-1} at 20 DAS was considered superior and might be suggested to realize higher yield, net return and benefit: cost ratio. Patel *et al*. (2018) also concluded that the integrated weed management treatments *i.e*. one hoeing at 15 days after sowing followed by 2 hand weeding at 25 and 45 days were found superior in reducing crop-weed competition and thereby increased growth and yield of soybean.

2.5 Competitive indices on maize + legume intercropping

Higher land equivalent ratio (LER) was achieved from intercropping of maize with pigeon pea by Patra *et al*. (1990); from intercropping of maize with groundnut by Mandimba (1995) and from maize intercropped with soybean by Kalia *et al*. (1992). Similarly, Ullah *et al*. (2007) in his experiment on intercropping achieved the highest land equivalent ratio (LER) of 1.62 from maize intercropped with soybean.

Banik *et al*. (2000) and Ghosh (2004) reported that in groundnut + maize intercropping system, the aggressivity value of groundnut was found to be negative and therefore, groundnut was considered as the less dominant crop in the system.

Mohan *et al*. (2005) reported that land equivalent ratio (LER) and area time equivalent ratio (ATER) were higher in maize + legume in 1:2 ratio than that of 1:1 ratio.

Sheoran *et al*. (2010) reported that relative crowding co-efficient (RCC) indicated that it was advantageous and biologically sustainable to grow black gram as intercrop with maize under rainfed conditions, which might be due to better plant compatibility.

Mallikarjuna *et al*. (2011) reported that paired row of maize with 2 rows of urdbean recorded a higher land equivalent ratio (LER) as compared to other row ratios and their sole crops.

Kheroar and Patra (2013) reported that land equivalent ratio (LER) in different intercropping system were always found to be greater than unity which indicated the yield advantage of intercropping system. Similarly, Sharma and Behera (2009) reported that land equivalent ratio (LER) and other competition functions were favourably influenced when intercropped with maize + green gram and maize + cowpea.

Mandal *et al*. (2014) reported that the highest land equivalent ratio (LER) and relative crowding coefficient (RCC) were obtained in maize + groundnut (2:4) followed by maize + soybean (1:2) combinations.

According to Layek *et al*. (2014), relative crowding coefficient (RCC) of legume intercropped with maize was higher in legume based intercropping system and relative crowding co-efficient (RCC) was adjusted in between legume row by changing the crop geometry.

Kheroar and Patra (2014) reported that the highest value of LER and ATER were obtained from maize + black gram (2:2) intercropping and 1:1

proportion of intercropping of maize + black gram resulted in higher values of agressivity.

Choudhary *et al*. (2014) reported that LER of maize + soybean increased from 17 to 53 percent. In general, it was noticed that with increase of row proportion, LER also got improved.

Kithan and Longkumer (2014) found that the highest LER was recorded in paired rows of maize + soybean (2:2) in intercropping. Jan *et al*. (2014) concluded that values of most of the intercropping indices were the highest for 2:2 maize + black cowpea row ratio and hence, it will be the most advantageous in terms of net yield and land utilization.

Haque *et al*. (2016) reported that intercropping systems increased land equivalent ratio (LER) with higher value of 1.71 as recorded under maize + soybean intercropping system followed by maize + groundnut intercropping with a value of 1.70. All the weed management treatments increased land utilization over weedy check. Weeding thrice and pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} recorded the maximum land equivalent ratio (LER) of 1.73 which were closely followed by pre-emergence application of alachlor @ 2.0 kg a.i.ha^{-1} as 1.70 and combined application of butachlor (pre-emergence) + quizalofop-ethyl (post- emergence) application as 1.69.

Manasa *et al*. (2018) reported that competition functions like land equivalent ratio (LER), relative crowding co-efficient (RCC), aggressivity (A) and competitive ratio (CR) prominently indicated the benefits of maize + legume intercropping system under South Odisha conditions.

2.6 Economics of maize + legume intercropping

Kalra and Gangwar (1980) reported that intercropping helped in increasing farm income on sustained basis. Quayyum and Maniruzzaman

(1995) reported that the maximum net return (`20,803 ha^{-1}) was obtained from Alachlor 1.5 kg a.i.ha^{-1} + HW at 40 DAS and Alachlor 2.0 kg a.i.ha^{-1} was the next in order which was followed by HW at 30 DAS. All intercropping combinations gave higher net return than their sole stands. Singh *et al.* (1995) also reported the highest net return from maize + black gram intercropped system.

Pandita *et al*. (1998) reported that among different cropping systems, maize + frenchbean in 1:2 row ratio proved to be the most beneficial and gave the highest benefit: cost ratio which was closely followed by maize + greengram in the same proportion. Hence, results indicated that maize + frenchbean in row ratio of 1:2 could be beneficial and sustainable intercropping system under Kashmir valley conditions.

Maize in association with legumes gave higher total yield and net return (Patra *et al*., 2000). Bharati *et al*. (2007) reported that maize based intercropping generated higher net return than sole crop of maize. Kamanga *et al*. (2010) opined that maize + legume intercropping was more productive and remunerative as compared to sole cropping.

Singh and Singh (2001) in their study of intercropping of maize with soybean noticed the advantage in paired row of maize with two rows of soybean.

Kumar *et al*. (2003) confirmed the importance of maize + soybean intercropping system in terms of yields and economic prospects in India. They observed the high mean maize equivalent yield of about 4262 kg ha^{-1}, LER (1.34), benefit: cost ratio (1.60) and net returns (₹ 6909 ha^{-1}) with 1:1 row ratio in maize + soybean intercropping system.

Sahu and Ambawatia (2003) reported the highest maize equivalent yield (MEY) with maize + pigeonpea intercropping system that might possibly be due to high market value of pigeonpea, followed by maize + soybean and maize + black gram intercropping system (1:1 or 2:2 row ratio).

Ullah *et al*. (2007) recorded a high LER of about 1.62 when maize was intercropped at 90 cm double row strips with soybean, which also indicated the higher land use efficiency and maize grain yield (6710 kg ha^{-1}) over sole cropping. Further, they also observed the maximum net income (₹ 56043.50 ha^{-1}) in intercropping over sole crop of maize (₹ 52653.50 ha^{-1}). Similar results were obtained by Khan *et al*. (1999) with high total relative yield with maximum LER (1.48) and gross income (₹ 23197 ha^{-1}) in maize + soybean intercropping system over sole cropping.

Mallikarjuna *et al*. (2011) recoded the maximum relative net returns of 1.28, 1.48, 1.56 and 1.40 under all weed control methods for paired row of maize with two rows of urdbean thereby indicated its economic viability among intercropping.

Dwivedi and Shrivastava (2011) reported that all the intercropping combinations of maize + black gram gave a higher net return than their sole crops. Under weed control practice, the maximum net return (₹ 20,803 ha^{-1}) was obtained from Alachlor 1.5 kg a.i.ha^{-1} + HW at 30 DAS.

It was found that growing of legumes in between maize rows in both 1:1 and 1:2 ratio of sowing were profitable in comparison to sole maize when differential cost of cultivation was taken into consideration. Intercropping with 1:2 ratio was found to be beneficial as it was recorded significantly higher values of RNR as compared to 1:1 proportions of intercropping. Maize + peanut in 1:2 ratio of intercropping recorded the highest RNR value of 2.01and maize + black gram (1:1) recorded the lowest RNR value of 1.32 (Kheroar and Patra, 2013).

Kithan and Longkumer (2014 and 2016) reported that the highest net return among the different intercropping treatments was recorded with 2:2 ratios of maize + soybean.

Kheroar and Patra (2014) concluded that maize when intercropped with legumes found to be beneficial and profitable. Maize + legume intercropping was found to be more advantageous with respect to maize equivalent yield and monetary returns in both the proportions of sowing (1:1 and 2:2) but 2:2 proportion appeared to be more remunerative.

Patel *et al*. (2015a) reported that maize intercropping with legumes *viz.*, black gram, greengram, cowpea and soybean gave a higher net return than sole crop of maize. He further reported that the highest net return was obtained by hand weeding (₹ 47884.84 ha^{-1}) followed by the application of metolachlor (₹ 47651.24) in maize + legumes intercropping system.

Haque *et al*. (2016) observed that cropping system significantly influenced the net return with the highest value of ₹ 21,360 ha^{-1} as recorded from maize + groundnut intercropping system and was statistically at par with that obtained under maize + soybean intercropping system (₹ 20,180.60 ha^{-1}). Among weed management treatments, pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} recorded the highest net return of ₹ 17,862 ha^{-1}. The lowest mean value of net return was recorded with weedy check (₹ 7713 ha^{-1}).

Cui *et al*. (2017) reported that planting patterns of maize + soybean 2:2 row ratio was the most profitable and had the highest yield advantage based on LER and economic benefits. Therefore, the highest yield of 2:2 row ratio in maize + soybean relay strip intercropping system can be attributed to the improved utilization of growth resources by the intercrop coordinates.

Sahu (2006) reported that the highest MEY in case of maize + pigeonpea/ soybean/ black gram intercropping systems was due to the highest market value of the component crops.

Dwivedi and Shrivastava (2011) recorded the highest net return of ₹ 17,493 ha^{-1} under maize + black gram (1:1) intercropping which was again registered the superiority of this planting geometry. It was followed by maize + black gram (2:1) as ₹ 13,500 ha^{-1}.

2.7 Cereal + legume intercropping on soil health improvement

Cereal + legume cropping system was advanced as one of the integrated soil fertility management practices consisting of growing two or more crops in the same space at the same time, which was practiced over the years and achieved the soil fertility restorations and crop yield in agriculture (Matusso *et al*., 2014b). The most common cropping system in developing countries consisted of growing several crops in association or in mixtures mainly being cereal and legume (Ouma and Jeruto, 2010).

Technologies that involved integrated soil fertility management practices (ISFM) with cereal + legume intercropping proved to improve soil fertility (Mucheru-Muna *et al*., 2010; Sanginga *et al*., 2009). Such technologies led to changes in global agriculture by searching for highly productive, sustainable and environment friendly cropping systems with renewed interest in cereal + legume cropping systems research (Crews *et al*., 2004). Studies conducted in Australia showed that legume produced an average of 225 kg N ha^{-1} and replaced over 60 percent of the nitrogen fertilizer requirement for optimum cereal production (Zablotowicz *et al*., 2011). Further, the contribution of legume crops on cereal crop yield indicated an increase in yields of crops planted after harvesting of legumes and contribution was often equivalent to those expected from application of 30-80 kg of fertilizer N ha^{-1} (Peoples *et al*., 2009).

Studies further indicated that intercropping cereals with legumes had sufficient capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen (Giller, 2001; Ndakidemi, 2006). Estimate indicated that, when cereal and legumes were intercropped, the legumes could fix up to 200 N kg ha^{-1} $year^{-1}$ under optimal field conditions (Giller, 2001). However, very limited information highlighted the effects of legume when inoculated with rhizobia and grown in diversified cereal + legumes cropping systems. Besides the benefit of yield and soil fertility improvement, cereal + legume intercropping could be seen to produce social benefits to both the land-holder and surrounding community such as productivity of various plant constituents and economic returns (Geno and Geno, 2001). Massawe *et al*. (2016) opined that cereal + legume intercropping system become one of the solutions for food security among small cereal producers due to unaffordability of chemical nitrogenous fertilizers and limited access to arable land. On-farm nitrogen contributions as achieved largely through biological nitrogen fixation in cereal + legume cropping systems proved to increase nitrogen content in the soils. Therefore, updated traditional cereal + legume intercropping practices (as opposed to promoting monocultures) offered the potential of specific technologies for soil fertility improvement that favour the small farmers.

Where legumes and cereals were intercropped, the cereal crop might benefit from the nitrogen fixed by the companion leguminous crop (Agegnehu *et al*., 2008). The amount of N fixed by the legume component in legume + cereal intercropping systems depended on several factors, such as species, plant morphology, density of component crops, type of management and competitive abilities of the component crops (Ofori and Stern, 1987).

Kadam *et al.* (1987) found that available nitrogen status of soil at harvest was significantly more in sole crop of black gram in sorghum + black gram intercropping system than the sole sorghum.

Beneficial effects of mono and intercropped legumes on subsequent cereal crops were well documented (Papastylianou, 1988). For instance, wheat yield increased after a maize + soybean intercrop and a maize + cowpea intercrop (Nair *et al*., 1979), after maize + groundnut or a maize + soybean intercrop (Searle *et al*., 1981), after pearl millet + several legumes intercrop (Patil and Pal, 1988). Barley yield also increased after oat (*Avena sativa* L.) + vetch (*Vicia sativa* L.) or peas (*Pisum sativa* L.) (Papastylianou, 1990). Various factors, such as an increase in organic matter, improved soil structure and, most importantly, increase in soil-N might account for this phenomenon.

Cereal + legume intercropping facilitated to maintain and improve soil fertility (Andrews, 1979). Similarly, Beedy *et al*. (2010) also reported that maize based intercropping with legume helped in improving soil health as well as yield of main crop. This practice contributed to long-term immobilization of nitrogen and controlled the growing dependence on nitrogenous fertilizers (Regehr *et al*., 2015). Additionally, it helped to maintain and improve the soil fertility because leguminous crops like soybean, cowpea and groundnuts accumulated nitrogen from 80 to 350 kg ha^{-1} (Mobasser *et al*., 2014). Therefore, we could improve nodules per plant, nitrogen fixation potential and ultimately nitrogen uptake by reducing nitrogen application rate from 240 to 180 kg ha^{-1} (Yang *et al*., 2014). In addition, maize intercropped with soybean significantly accumulated high total N than the sole maize and thus improved the system capacity (Zhang *et al*., 2015). Hence, cereal + legume intercropping was a sustainable land management practice (Iqbal *et al*., 2019).

Sharma and Choubey (1991) reported that intercropping soybean and green gram with maize showed a little improvement in the nitrogen status of the soil but there was a slight reduction in phosphorus and potassium contents.

FAO (2001) reported that intercropping practices that included legumes promote rhizobial + legume symbiotic relationships that lead to biological nitrogen fixation.

Intercropping increased available soil N and decreased both soil P and K as compared to initial and available soil N, P and K content after sole maize. Available soil N, P and K content varied with the kind of intercrops. However, maize + soybean followed by maize + black gram recorded the highest available soil N at 1:1 row ratio and available soil P and K at 2:1 row ratio among various intercropping systems (Padhi and Panigrahi, 2006).

Nagar *et al*. (2016) reported that the lowest soil pH (7.97) and electrical conductivity (0.15 dS/m) were observed in pigeonpea + black gram followed by pigeonpea + greengram intercropping systems and sole pigeonpea. Whereas, higher organic carbon (5.56 g kg^{-1}), available nitrogen (182.8 g kg^{-1}), phosphorus (22.5 g kg^{-1}) and potassium (431.8 g kg^{-1}) were estimated in pigeonpea + black gram and pigeonpea + greengram intercropping systems. The results indicated that significantly higher intercropping microbial population was recorded with pigeonpea + black gram which was closely followed by pigeonpea + greengram intercropping as compared to sole pigeonpea.

Patel *et al*. (2017) also reported that among the intercropping systems, maize + green gram (paired raw 2:2) recorded maximum available N and P_2O_5 content after crop harvest in soil followed by maize + green gram (1:1).

MATERIALS AND METHODS

The present investigation entitled **"Evaluation of Maize (*Zea mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition"** was carried out in the Experimental Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during the two consecutive *kharif* seasons of 2016 and 2017. The details of experimental materials used and research methodologies adopted during the course of experimentation were discussed in this chapter.

3.1 General information

3.1.1 Geographical location of the Experimental farm

The experimental farm was located at an altitude of 295 m above mean sea level within the geographical location at 25.450357^{o}N latitude and 93.530708^{o} E longitude.

3.1.2 Climate and Weather conditions of the location

The experimental farm lies in humid subtropical region with an annual rainfall ranging from 2000 to 2500 mm. The mean temperature during the growing season ranged from 24^{0}C to 32^{0}C and atmospheric humidity ranged from 71% to 92%.

3.1.3 Weather during crop season

Detailed observations on maximum and minimum temperature, relative humidity, rainfall and sunshine hour during the crop growing seasons of the year 2016 and 2017 were recorded from the Agro Meteorological Observatory, Indian Council of Agricultural Research, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland which was within 100 meters from the experimental field and presented as Table 3.1(a) and 3.1(b) and graphically depicted as Figure 3.1 and 3.2 respectively.

Table 3.1(a) Mean weekly meteorological data during the experimental period (2016)

Month	Week no. of the year	Date	Temperature (^{0}C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hr)
			Min	Max	Morning	Evening		
May	21	23-29	22.6	30.9	92	67	55.7	5.2
	22	30-05	23.1	31.9	92	70	42.6	5.1
June	23	06-12	24.0	34.7	87	63	3.9	6.9
	24	13-19	25.8	32.9	90	72	71.3	3.3
	25	20-26	24.5	32.9	90	71	85.5	3.0
	26	27-03	25.3	33.6	89	68	30.2	3.8
July	27	04-10	24.8	33.3	92	70	133.2	3.4
	28	11-17	25.3	33.4	91	79	28.1	4.0
	29	18-24	24.8	32.0	91	67	57.1	0.5
	30	25-31	23.9	30.6	93	73	36.6	1.2
August	31	01-07	24.8	34.2	92	65	9.6	5.3
	32	08-14	24.1	32.6	94	72	110.9	3.5
	33	15-21	24.6	34.6	91	69	126.4	3.9
	34	22-28	24.4	33.7	91	68	15.2	4.5
	35	29-04	23.9	33.9	94	71	149.9	3.9
September	36	05-11	24.6	32.9	93	70	53.6	4.4
	37	12-18	23.7	32.4	94	74	94.1	3.4
	38	19-25	23.6	32.7	94	74	69.9	5.1
	39	26-02	23.9	32.2	95	74	60.0	5.3
October	40	03-09	23.4	33.9	94	66	2.8	8.2
Average			24.25	32.96	91.95	70.15	61.83	4.19

Source: Agro meteorological observatory, Indian Council of Agricultural Research, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland

Table 3.1(b) Mean weekly meteorological data during the experimental period (2017)

Month	Week no. of the year	Date	Temperature (^0C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hr)
			Min	Max	Morning	Evening		
May	21	22-28	22.0	32.4	92	66	8.9	4.8
	22	29-04	22.9	30.3	92	75	75.3	2.3
June	23	05-11	23.1	33.5	92	61	4.8	7.9
	24	12-18	24.1	31.1	95	83	127.9	2.4
	25	19-25	24.0	30.8	92	72	22.5	3.1
	26	26-02	24.4	31.8	93	75	134.4	1.7
July	27	03-09	24.7	31.8	94	80	153.0	1.9
	28	10-16	23.6	29.9	95	74	104.5	3.8
	29	17-23	24.7	31.6	93	77	131.8	3.6
	30	24-30	24.7	31.9	93	73	61.5	3.3
	31	31-06	25.0	33.3	92	66	33.5	6.4
August	32	07-13	25.1	31.8	93	74	81.2	0.5
	33	14-20	24.5	31.0	95	73	50.3	3.1
	34	21-27	24.1	32.3	93	74	171.9	6.1
	35	28-03	24.6	30.7	95	75	92.8	2.7
September	36	04-10	24.8	33.0	94	65	4.5	5.1
	37	11-17	24.2	31.4	95	74	38.3	4.4
	38	18-24	24.8	31.2	96	76	8.8	4.4
	39	25-01	24.3	31.6	96	80	155.9	4.5
Average			24.18	31.65	93.68	73.31	66.3	3.78

Source: Agro meteorological observatory, Indian Council of Agricultural Research, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland.

3.1.4 Cropping history of the experimental field

The details of cropping history of the experimental field for last three years of experimentation were as given below:

Sl. No	Year	Kharif	Rabi	Zaid
1	2013-14	Maize	Toria	Green gram
2	2014-15	Maize	Toria	Green gram
2	2015-16	Maize	Toria	Green gram

3.1.5 Soil Chemical properties of the experimental field

In order to assess the chemical properties of soil for the experimental field, soil samples (0-15 cm) were taken before conducting the experiment considering all possible precautions as prescribed for soil sampling (Black *et al.,* 1965).

The soil samples were brought into the laboratory, air dried and crushed to pass through 20 mm mesh sieve. The processed soil samples were subjected to appropriate soil analysis and results thus obtained were presented in Table 3.2.

Table 3.2: Soil Chemical properties of the experimental field

Soil property	Initial Value	Interpretation	Method of Analysis
pH	**4.5**	**Acidic**	Digital pH meter (Jackson, 1967)
Organic carbon (%)	**0.4**	**Low**	Colorometric method (Walkley and Black , 1934)
Available nitrogen N (kg ha^{-1})	**220**	**Low**	Kjeldahl method (Subbiah and Asija, 1956)
Available phosphorus P_2O_5 (kg ha^{-1})	**21.1**	**Medium**	Colorimetrically using ascorbic acid method. (Bray and Kunz, 1945)
Available Potassium K_2O (kg ha^{-1})	**224**	**Medium**	Flame photometer (Jackson, 1967)

3.2 Experimental materials

3.2.1 Crops and varieties

The general descriptions of the crop varieties used in the present experiment were given below:

a) Maize variety RCM-76

Maize variety RCM-76 was a promising composite variety obtained from ICAR Research Complex for NEH Region, Nagaland Centre. This variety was short duration, semi dwarf and drought tolerant. It performed well in the region.

b) Black gram variety KU-301

The black gram variety KU-301 was recommended for general cultivation in Assam and seeds of the variety were obtained from RARS, Shillongani, Nagaon. Farmers in the state of Nagaland preferred this variety because of its green colour, taste and semi-dwarf nature.

c) Soybean variety JS-335

The soybean variety JS-335 was semi-dwarf and determinate in habit with profuse branching. Flowers were purple in colour. Pods were covered with gray hairs at maturity. Seeds were yellow, medium large with black hilum. The variety performed well in the region.

3.2.2. Chemical fertilizers

Nitrogen as Urea, Phosphorus as Single Super Phosphate and Potash as Muriate of Potash were utilized in the present experiment and obtained from Brahmaputra Valley Fertilizer Corporation, Namrup for Urea, Tata Chemicals

Ltd, Mumbai for Single Super Phosphate and Muriate of Potash through an agency M/S K Angami store, Nagaland.

3.2.3 Chemical weedicide

Pendimethalin 30 EC as pre-emergence herbicide from Dhanuka was used in the present investigation.

3.2.4 Plant protection chemicals

Carbofuran and cypremetherin were used for control of stem borer in maize and blister beetle in black gram and soybean respectively.

3.3 Experimental method

3.3.1 Experimental details

The experimental details for both the years were same and as given below:

I.	Experimental design	: Randomized Block Design
II.	Treatment	: Two factors i. Planting geometry ii. Weed management
III.	Crop	: Main crop- Maize Inter crops- Black gram & Soybean
IV.	Varieties	: Maize (Var. RCM-76) : Black gram (Var. KU-301) : Soybean (Var. JS-335)

V. Spacing

a. Row to row spacing : 60 cm (Addititive series)

: 50 cm (Paired row)

b. Plant to plant spacing : 25 cm

VI. Treatment combinations : 12

VII. Number of replications : 3

VIII. Total number of plots : 36

IX. Net plot size : 4.8 x 4.0

X. Gross Plot size : 5.7 x 4.5

XI. Inter replication spacing : 1.0 m

XII. Inter plot spacing : 0.75 m

XIII. Gross experimental area : 1291.5 m^2

N.B. A plot of sole crop each of maize, black gram and soybean having the same area as that of each treatment was maintained in each replication following the recommended package of practices of the crop. The yield data of these sole crops were used in the calculation of competitive indices only.

3.3.2 Treatment Details

The different levels of treatment and their combinations in the present experiment were given below:

A. Planting geometry

1. Maize + black gram (1:1 row ratio in additive series) = S_1
2. Maize + black gram (2:2 row ratio in paired row) = S_2
3. Maize + soybean (1:1 row ratio in additive series) = S_3
4. Maize + soybean (2:2 row ratio in paired row) = S_4

B. **Weed management**

1. Weedy check = W_0

2. Pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS = W_1

3. Two hand weeding at 20 and 40 DAS = W_2

C. **Treatment combinations**

The different treatment combinations were as under:

Treatments	Treatment combinations	Symbols
T_1	Maize + black gram (1:1) + weedy check	S_1W_0
T_2	Maize + black gram (1:1) + pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS	S_1W_1
T_3	Maize + black gram (2:1) + two hand weeding at 20 and 40 DAS	S_1W_2
T_4	Maize + black gram (2:2) + weedy check	S_2W_0
T_5	Maize + black gram (2:2) + pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS	S_2W_1
T_6	Maize + black gram (2:2) + two hand weeding at 20 and 40 DAS	S_2W_2
T_7	Maize + soybean (1:1) + weedy check	S_3W_0
T_8	Maize + soybean (1:1) + pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS	S_3W_1
T_9	Maize + soybean (1:1) + two hand weeding at 20 and 40 DAS	S_3W_2
T_{10}	Maize + soybean (2:2) + weedy check	S_4W_0
T_{11}	Maize + soybean (2:2) + pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS	S_4W_1
T_{12}	Maize + soybean (2:2) + two hand weeding at 20 and 40 DAS	S_4W_2

3.4 Calendar of cultural operations

The dates of important operations starting from field preparation to crop harvest were given as in Table 3.3.

Table 3.3: Details of cultural operations

Sl. No.	Operations	2016	2017
1.	Field Preparation (Ploughing + Harrowing + Planking)	23.05.2016	18.05.2017
2.	Layout	28.05.2016	24.05.2017
3.	Basal application of fertilizer	28.05.2016	24.05.2017
4.	Seed Sowing	28.05.2016	24.05.2017
5.	Spraying of Pendimethalin (pre-emergence)	30.05.2016	26.05.2017
7	Thinning in intercropping	12.06.2016	09.06.2017
8	Hand-Weeding		
	i. First hand weeding	17.06.2016	13.06.2017
	ii. Hand weeding after weedicide application	27.06.2016	23.06.2017
	iii. Second hand weeding	07.07.2016	03.07.2017
9	Plant protection		
	i. Stem borer	22.06.2016	18.06.2017
	ii. Blister beetle	14.08.2016	
10	Earthing up and top dressing of nitrogen in maize crop	02.07.2016	28.06.2017
11	Harvesting		
	i. Black gram	21.08.2016	15.08.2017
	ii. Maize	31.08.2016	26.08.2017
	iii. Soybean	04.10.2016	30.09.2017

3.5 Cultural practices adopted

3.5.1 Field Preparation

Field was prepared according to the requirement of main crop *i.e.* (maize) in maize + black gram/soybean intercropping system. As a general rule, maize requires a well pulverized but compact seedbed for good and uniform germination. Therefore, field was ploughed and cross ploughed once with a tractor drawn disc plough on optimum workable soil moisture. Thereafter, it was harrowed twice followed by planking to provide a good tilth.

3.5.2 Fertilizer Application

Fertilizer requirement of the crops were met through Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O).

a) Maize intercrop and sole crop of maize

Intercrop and sole crop of maize received 100% recommended dose of fertilizer *i.e.*100 kg ha^{-1} N + 60 kg ha^{-1} P_2O_5 + 40 kg ha^{-1} K_2O. Nitrogen was applied in two equal split doses one as basal dressing and another at knee high stage. However, the common doses of phosphorus (60 kg ha^{-1}) and potassium (40 kg ha^{-1}) were applied as basal dressing at the time of sowing.

b) Black gram and Soybean as intercrop

No additional dose of fertilizer was given to black gram and soybean in intercropping with maize.

c) Black gram and soybean as sole crop

For sole crop of black gram and soybean, full recommended dose of fertilizer *i.e.* 30 kg ha^{-1} N + 40 kg ha^{-1} P_2O5+ 15 kg ha^{-1} K_2O and 20 kg ha^{-1} N

+ 60 kg ha^{-1} P_2O_5 + 30 kg ha^{-1} K_2O respectively were applied as basal dressing at the time of sowing.

3.5.3 Seed rate

The seed rate of maize as sole crop and intercrop remained same as 20 kg ha^{-1}, while seed rate of black gram as sole crops and intercrops were 14 kg ha^{-1} and 7 kg ha^{-1} respectively. Similarly, the seed rate of soybean as sole crop and intercrops were 60 kg ha^{-1}and 30 kg ha^{-1} respectively.

3.5.4 Thinning

Thinning of maize, black gram and soybean was done within 15 days after sowing to keep one healthy plant per hill with the plant to plant spacing of 25 cm in maize and 10 cm in black gram and soybean in both the years of experimentation.

3.5.5 Earthing up

Earthing up was done for all the treatments and sole crops on 35 DAS using appropriate farm tools *e.g*. Spade, hand hoe, etc.

3.5.6 Plant protection measures

Routine monitoring of pest and diseases for the experimental crops were performed. For control of maize stem borer infestation, carbofuran 3g @ 5-6 granules per plant was applied on the leaf whorl of plants. Due to heavy infestation of blister beetle in black gram and soybean during flowering stage, beetles were controlled by using cypremethrin 3ml/litre of water.

3.5.7 Harvesting

Black gram (KU-301) was first to mature followed by maize var. RCM-76 while the soybean (JS-335) was last to mature. The border rows were harvested first and removed from the individual plots leaving only the net plot area.

a) Maize

The maize crop var. RCM-76 was harvested manually when the silk of the cob turn brown yellow and totally dried in more than 80 percent cobs. Cobs were separated from stalks manually and stalks were cut close to the ground with the help of sickle/dao. The plot wise cobs were then collected in cloth bags and stalks were bundled and kept for sun drying.

b) Black gram

The black gram var. KU-301 was harvested manually by hand picking of matured pods twice and lastly by cutting with sickle at the ground level when more than 80 per cent pods in all plots turned completely dark brown in colour giving dry appearance. The harvested crop from net plot for grain yield was left as such in respective plots for sun drying for a period of about 3-4 days.

c) Soybean

The soybean var. JS-335 was harvested manually with sickle when more than 80 per cent pods in all plots turned completely dark yellow in colour giving dry appearance. The harvested crop from net plot area for grain yield was left as such in respective plots for sun drying for a period of about 3-4 days.

3.5.8 Threshing

Each bundle was weighed after proper sun drying and then threshed individually. The grain yield of maize, black gram and soybean were weighed and recorded separately after winnowing and cleaning. The stover yields were calculated by subtracting grain yield from the dried bundle weight of the respective crops.

3.6 Planting geometry

a) 1:1 method of planting

Maize sowing as main crop was done by dibbling 2 seeds in furrows at the spacing of 60 cm row to row and 25 cm plant to plant. The black gram and soybean as intercrop, were sown at row to row and plant to plant spacing of 30 cm and 10 cm respectively for both sole and intercrops in 1:1 method of planting.

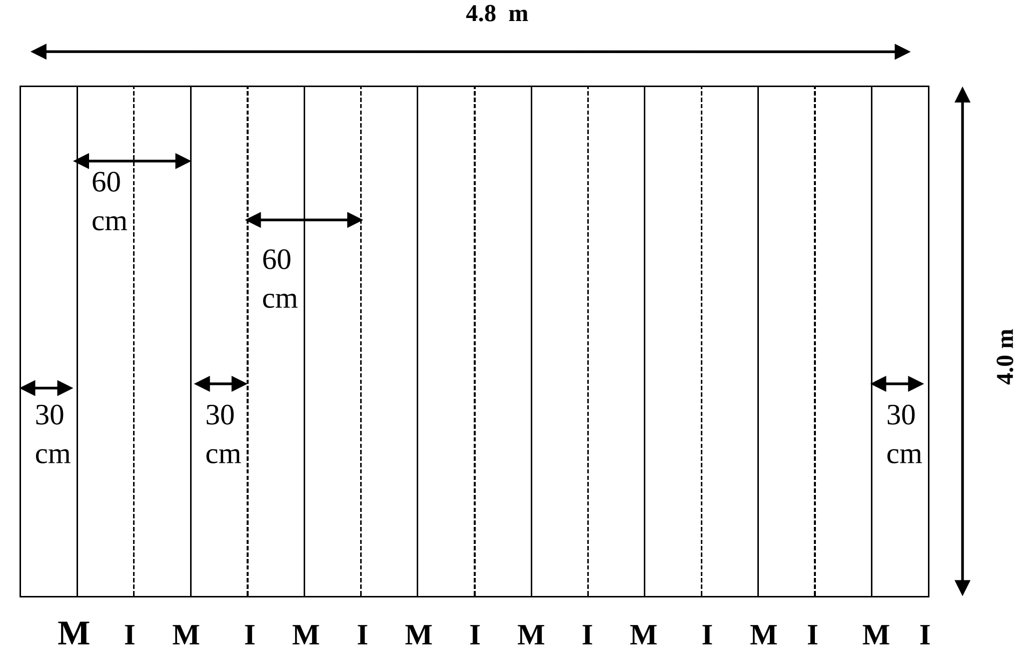
b) 2:2 method of planting

In 2:2 method of planting, paired maize row spacing was 50 cm row to row and 25 cm plant to plant. In the case of black gram and soybean as intercrop, row to row spacing between maize and legume was 20 cm and legume to legume was 30 cm and plant to plant spacing of legume crops were maintained at 10 cm.

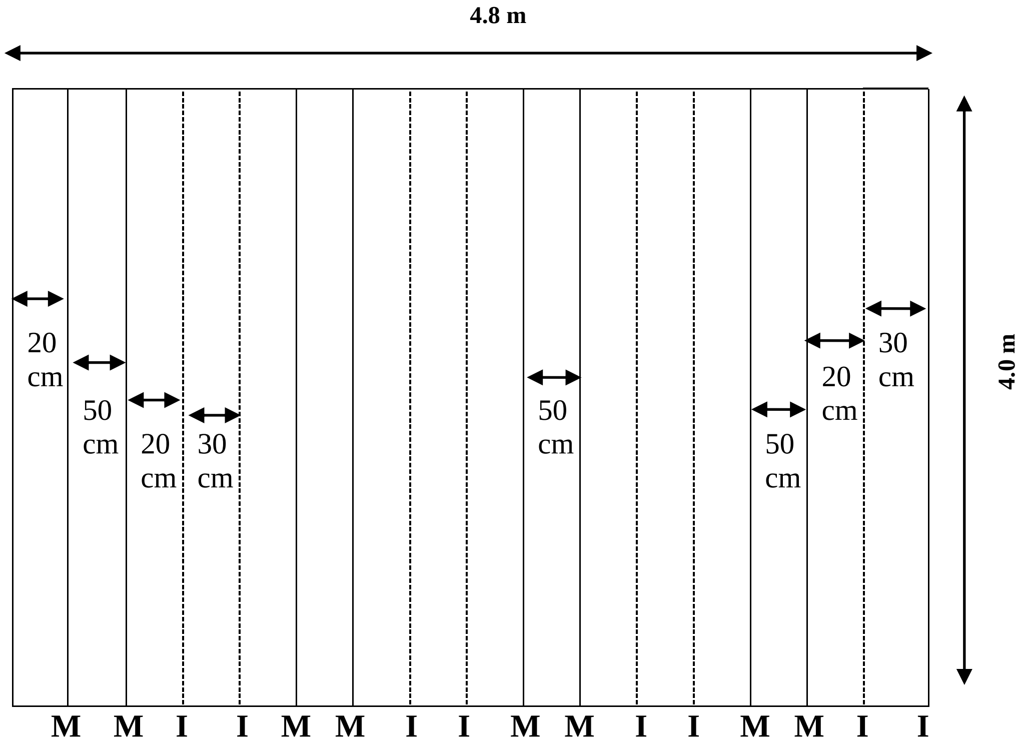
c) Sole crops

For maize, black gram and soybean as sole crops, planting was done by dibbling in furrows at the spacing of 60 cm row to row and 25 cm plant to plant for maize crop and 30 cm row to row and 10 cm plant to plant for legume crops.

d) Plot wise layout of planting geometry:



Maize single row + Intercrops (1:1)



Maize paired row + Intercrops (2:2)

3.7 Weed management

3.7.1 Herbicide application

As per treatment, herbicide was applied as aqueous solution using 500 litres of water per hectare. As per gross plot area, the required quantities of herbicide and water were measured and sprayed using low volume sprayer. Pendimethalin 30 EC @ 1.0 kg a.i.ha^{-1} was applied uniformly on the second day after sowing.

3.7.2 Hand weeding

For manual hand weeding, hand hoe of convenient size was used for effective weeding and first hand weeding was done at 20 DAS. The second hand weeding with the help of hand hoe was performed at 40 DAS. For herbicide cum hand weeding treatment, hand weeding was performed at 30 DAS. For sole crops *viz*., maize, black gram and soybean, two hand weeding at 20 and 40 DAS were practiced.

3.8 Sampling procedure, plant growth parameters and data collection

3.8.1 Sampling procedure

Simple random sampling was followed in the present studies. A single plant selected using random number table was taken as a sampling unit. Five such randomly selected plants per plot for maize and black gram or soybean make the sample size of each plot. All the randomly selected plants in each plot were tagged for taking observations on plant growth parameters. Data on grain yield and stover yield were recorded from three undisturbed rows (without border plants) for all the crops and grain yield and stover yield per unit area were estimated.

3.8.2 Plant Growth parameters and data collection

A. Maize

1. Plant height (cm)

Plant height was measured with the help of a meter scale from the base of plant at ground level to the tip of the highest leaf at 30, 60 and 90 DAS. The mean plant height in cm at 30, 60 and 90 DAS for the plot was calculated as average of five plants.

2. Number of leaves plant^{-1}

Observations on number of leaves plant^{-1} were recorded from five tagged plant in each plot at 30, 60 and 90 days after sowing and the average was recorded.

3. Stem diameter (cm)

Stem diameter was measured with the help of a digital Vernier Caliper in cm at the middle of the stem at 30, 60 and 90 days after sowing and the average was recorded.

4. Leaf area index

Leaf area index was measured by using Biovis leaf area scanner from five randomly selected plants in each plot, as destructive sample at 30, 60 and 90 DAS.

$$\text{Leaf area index} = \frac{\text{Leaf area /plant}}{\text{Ground area /plant}}$$

5. Days to 50 % tasseling

The number of days from the date of sowing to the date on which half of the number of plants in a plot showed tasseling was recorded as days to 50% tasseling.

6. Days to 50% silking.

Days to 50 % silking was recorded as the number of days from the date of sowing to the date on which half of the plants in a plot showed silking.

7. Yield attributes

The following observations on yield attributes were recorded:

i. Number of cobs plant^{-1}

Total number of cobs of the five tagged plants were counted and average worked out as the mean number of cobs plant^{-1}.

ii. Number of grain rows cob^{-1}

Number of grain rows cob^{-1} of five tagged plants were counted and average was recorded as the number of grain rows cob^{-1}.

iii. Number of grains row^{-1}

Number of grains in each grain row of the cobs from the five tagged plants were counted and average value was recorded as number of grains row^{-1}.

iv. 1000 grain weight (g)

Thousand grains from the representative sample of each plot were counted and weighed after properly sun dried.

8. Grain yield (kg ha^{-1})

The cobs from the plants growing in the central undisturbed three rows (without border plants) were collected and stripped off their husk, air dried for one week and these were shelled separately. The shelled grains were cleaned and sun dried to obtain a constant weight. This will give the grain yield of the unit area and thereafter, converted to grain yield per hectare.

9. Stover yield (kg ha^{-1})

The plants used for taking grain yield of each plot were cut from ground level after removal of the cobs. The stover was sun dried to obtain a constant weight which gave the stover yield in kg per plot and then it was computed into kilogram per hectare.

B. Black gram and soybean

1. Plant height (cm)

Height of randomly selected five plants from each plot was measured from base of the plant up to the tip of main stem at 30, 60 DAS and at harvest for black gram and 30, 60 and 90 DAS for soybean. The average plant height in centimetre was obtained by taking the mean of five plants.

2. Number of primary branches plant^{-1}

Five random plants selected for recording plant height were used for counting the number of primary branches plant^{-1}. All the primary branches arised from the main shoot were counted at different stages of crop *i.e.* 30, 60 DAS and at harvest for black gram and 30, 60 and 90 DAS for soybean as number of branches plant^{-1} and average value was recorded.

3. Number of leaves plant^{-1}

Observations on number of leaves plant^{-1} were recorded as the average of random five tagged plant at 30, 60 DAS and at harvest for black gram and 30, 60 and 90 DAS for soybean.

4. Leaf area index

Leaf area index was measured by using Bovis leaf area scanner from five randomly selected plants in each plot by using destructive samples at 30, 60 DAS and at harvest for black gram and 30, 60 and 90 DAS for soybean.

$$\text{Leaf area index} = \frac{\text{Leaf area /plant}}{\text{Ground /plant}}$$

5. Number of nodules plant^{-1}

The number of nodules were counted from randomly selected five destructive plants and their average was calculated as the number of nodules plant $^{-1}$ at 30 and 60 DAS.

6. Yield components

i. Number of pods plant^{-1}

Total numbers of pods of the five tagged plants were counted and average value was worked out as the average number of pods plant^{-1}.

ii. Number of seed pod^{-1}

The selected five tagged plants were used for counting the number of seeds pod^{-1}. Pods were threshed and their seeds were counted to compute the number of seeds pod^{-1}.

iii. 1000 seed weight (g):

Randomly selected 1000 seeds from the seed yield samples of each plot were used to record 1000 seed weight.

7. Seed yield (kg ha^{-1}):

All the plants harvested from each plot for obtaining seed yield were sun dried and brought to the threshing floor, threshed, cleaned and seed yield per plot was recorded and thereafter, converted to seed yield kg ha^{-1}.

8. Stover yield (kg ha^{-1}):

Before threshing, the total weight of stover with pods was recorded for each plot. The stover yield in kg per plot was recorded after subtracting the weight of seed yield from the total weight of the stover with pods and converted to seed yield kg ha^{-1}.

3.9 Weed management sampling procedures and data collection

3.9.1 Weed species

All the available weed flora of the experimental field were collected and identified following Naidu (2012).

3.9.2 Weed population

Weed population was studied from a randomly selected quadrate of 100cm×100cm.The weeds growing within one quadrate were identified as monocot and dicot and counted at 30, 60 and 90 days or at harvest after sowing. Separate counts were recorded for monocot and dicot weeds. The data were subjected to $\sqrt{X} + 0.5$ transformation to normalise their distribution (Gomez and Gromez, 1984).

3.9.3 Weed biomass

After collecting the fresh weeds from each plot, the fresh weight of weeds for each plot was recorded with the help of an electronic/digital balance and recorded as fresh weight. The fresh weed was put in an envelope, sun dried and transferred to a hot air oven at 65±5^{o}C for 48 hours till a constant weight was obtained. Further, dry weight was measured. The weed samples were collected at 30, 60 and 90 DAS or at harvest.

3.10 Competitive Indices

3.10.1 Land equivalent ratio (LER)

Land Equivalent Ratio (LER) was calculated following Willey (1979) as under:

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where:

Yaa = pure stand yield of species 'a'

Ybb = pure stand yield of species 'b'

Yab = mixture yield of "a" (when combined with "b")

Yba = mixture yield of "b" (when combined with "a")

3.10.2 Area Time Equivalent ratio (ATER)

In the present studies, the method used by Hiebsch (1980) was followed for calculation of ATER.

ATER= (LERa x LERb x DC) Dt

Where,

LER is land equivalent ratio of crop,

DC is duration (days) taken by crop,

Dt is days to intercropping system from planting to harvest.

Hiebsch (1980) interpreted ATER as under:

When,

ATER > 1, it implies yield advantage of intercropping.

ATER = 1, it implies no effect of intercropping.

ATER< 1, it implies yield disadvantage of intercropping.

3.10.3 Relative crowding coefficient (RCC)

RCC was calculated following the formulas as given by De Wit, (1960).

$K = (K_{cereal} \times K_{legume})$

Where,

K = RCC of the intercropping system

K_{cereal} = RCC of intercropped cereal

K_{legume} = RCC of intercropped legume

$$K_{cereal} = \frac{Yab \times Zba}{(Yaa - Yab) \times Zab}$$

$$K_{legume} = \frac{Yba \times Zab}{(Ybb - Yba) \times Zba}$$

Yab = yield of cereal ‘a’ in intercropping

Zba = sown proportion of legume ‘b’ in intercropping

Yaa = yield of cereal ‘a’ in sole cropping

Zab = sown proportion of cereal ‘a’ in intercropping

Yba = yield of legume ‘b’ in intercropping

Ybb = yield of legume ‘b’ in sole cropping

When the value of the product of two coefficients ($K_{cereal} \times K_{legume}$) is higher than one (>1), there is a yield advantage in the intercropping. However, if the value of K is one (1), there is no yield advantage/disadvantage in the system. If the value of K is less than one (<1), there is competition between intercrops and associated crops with disadvantage in intercropping.

3.10.4 Aggressivity (A)

The aggressivity value (A) of a cereal + legume intercropping system was derived from the following formula as given by Mc Gilchrist, 1965.

$$A_{cereal} = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

$$A_{legume} = \frac{Yba}{Yba \times Zba} - \frac{Yab}{Yaa \times Zab}$$

Where,

Yab = yield of cereal ‘a’ in cereal + legume intercropping system

Yaa = yield of cereal ‘a’ in pure stand (sole cropping)

Zab = sown proportion of cereal ‘a’ in intercropping

Yba = yield of legume ‘b’ in cereal + legume intercropping system

Ybb = yield of legume ‘b’ in pure stand (sole cropping)

Zba = sown proportion of legume ‘b’ in intercropping

When the value of A becomes zero, none of the crops are considered as aggressive or both crops are equal in competition. If the value of A becomes positive, then cereal crop is considered as aggressive or dominant over intercropped legume. If the value of A becomes negative, then intercropped legumes are considered as aggressive or dominant over cereals.

3.10.5 Competitive ratio (CR)

Competitive ratio (CR) was calculated by the following formula as given by Willey and Rao (1980).

$$CRa = \frac{LERa}{LERb} x \frac{Zba}{Zab}$$

$$CRb = \frac{LERb}{LERa} x \frac{Zab}{Zba}$$

Where,

CR = Competition Ratio of ‘a’ in the mixture over ‘b’

LERa = LER of component ‘a’

LERb = LER of component ‘b’

Z ba = sown proportion of component ‘b’ in combination with ‘a’

Z ab = sown proportion of component ‘a’ in combination with ‘b’

If the values of CR<1, there is a positive benefit. It means there is limited competition between component crops and they can be grown as intercrops (Ghosh 2004). However, if the value is higher than one (CR>1), there is a negative impact. In this condition, the competition between intercrops in the association is too high, and they are not recommended to grow as intercrops. The competition ratio (CR) of legume and intercrop cereal has an inverse relationship.

3.10.6 Relative Value Total (RVT)

RVT was calculated by the following formula as given by Vandermeer, (1992).

$$RVT = \frac{ap1 + bp2}{am1}$$

Where, ' a' is the price of the main crop, 'b' is the price of secondary crop, p1 is the yield of the main crop in intercropping, p2 is the yield of the secondary crop of intercropping, m1 is the yield of the sole crop of the main crop species.

If RVT is bigger than 1, the intercropping is economically preferable; whereas, if RVT is smaller than 1, the pure cropping is preferable. If RVT is equal to 1, neither of the methods is economically superior to the other.

3.10.7 Maize equivalent yield (MEY)

According to Sarma (2014), maize equivalent yield (MEY) was calculated on the basis of prevailing market prices of both maize and intercrop as given below:

$$MEY = Ym \times \frac{Pm}{Pm} + Yi \times \frac{Pi}{Pm}$$

Where,

MEY= Maize equivalent yield

Ym = Yield of maize

Yi = Yield of intercrop

Pm = Price of maize

Pi = Price of intercrop

3.11 ECONOMICS (₹ ha^{-1})

Net return (ha^{-1}), return per rupee investment and benefit cost ratio, were computed with the help of following relations.

i. Net Return (ha^{-1}) = Gross return (ha^{-1}) – Cost of cultivation (ha^{-1})
ii. Return per rupee investment = Gross return (ha^{-1}) /Total cost of cultivation (ha^{-1})
iii. Benefit: Cost ratio = Net return (ha^{-1}) / Total cost of cultivation (ha^{-1})

The cost of cultivation, gross return, net returns, return per rupee investment and benefit cost ratio of different treatments were worked out on the basis of prevailing market prices. Farm power and labour for different operations *i.e*. ploughing, harrowing, sowing, weeding, harvesting, shelling, etc. were calculated ha^{-1} as per normal rates prevalent at the Research farm, ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani, Nagaland. The cost of fertilizers plant protection chemicals and seeds were considered at market price.

3.12 Soil health studies

3.12.1 Soil sample collection

Five soil samples were collected randomly from plough layer depth with the help of soil auger before sowing and after harvesting of crops from each plot following Black *et al.,* 1965. Composite soil samples, one for before sowing and another for after harvesting were made separately. The samples were mixed thoroughly and dried in air, crushed, sieved through 2 mm sieve.

The soil samples so prepared were subjected to chemical analysis for evaluating soil fertility status following standard procedures.

3.12.2 Soil chemical analysis

a. Soil pH

The pH of the soil in 1:2.5 soil water suspensions was determined by digital pH meter (Jackson, 1967).

b. Organic carbon (%)

The organic carbon content of the soil was determined by rapid titration method (Walkley and Black, 1934) and the results were expressed in percentage.

c. Available Nitrogen (kg ha^{-1})

The available nitrogen in the soil was determined by alkaline permanganate method as given by Subbaiah and Asija (1956) with the help of Kelpus nitrogen analyser and the results were expressed in kg ha^{-1}.

d. Available Phosphorus (kg ha^{-1})

The available phosphorus content was determined by extracting with 0.03N NH_4F+0.025 N HCl (Bray and Kuntz, 1945) and the phosphorus content was estimated colorimetrically using ascorbic acid method.

e. Available Potassium (kg ha^{-1})

The available potassium content was determined in neutral normal ammonium acetate extract using flame photometer (Jackson, 1967).

3.12.3 Soil Microbial Analysis.

1. **Soil sample collection and sample preparation for microbial analysis**

Soil sample for microbial analysis was collected from each plot at an interval of 30 days *i.e.* 30, 60 and 90 DAS. The collected soil samples were carried in the soil laboratory and kept air dry. Further, soil samples were prepared for microbial analysis through serial dilution method as follows: Five test tubes containing 9 ml of sterile distilled water were taken. One test tube containing 10 ml of sterile distilled water was taken and added 1 g of soil to the test tube. Thereafter, the soil was mixed thoroughly with the sterile distilled water. Then, 1 ml of microbial suspension was added to another test tube containing 9 ml of sterile distilled water and thoroughly mixed. Further, 1ml of microbial suspension was added to another test tube containing 9ml sterile distilled water. The same step was repeated serially for other test tubes. In this way the microbial suspension was diluted 10 folds. Finally, 100 µl of diluted suspension was poured into the surface of Nutrient agar plate and spread by "L" shaped spreader (Microbiology Practical Guide (A), 2010). The bacteria can thus be isolated and counted by C.F.U *i.e.* Colony Forming Unit. The same procedure was carried out in actinomycetes, fungi and phosphate solubilizing bacteria (PSB).

a) Bacteria

i. Aerobic non symbiotic nitrogen fixing bacteria

Count of aerobic non-symbiotic nitrogen fixing bacteria was made in nitrogen free agar medium (Jensen, 1930a).

ii. Phosphate solubilizing bacteria (PSB)

Count of phosphate solubilising organisms was done by solidified Pikovskaia's medium (Pikovskaia, 1948).

b) Fungi

Martin's rose Bengal streptomycin agar medium (Martin, 1950) was used for counting fungi.

c) Actinomycetes

Jensen's agar medium was used for the enumeration of actinomycetes, (Jensen, 1930b).

3.13 Statistical analysis

All the experimental data were subjected to statistical analysis by adopting appropriate method of Analysis of Variance as described by Gomez and Gomez (1984). Pooled analyses of data were also carried out to establish the trend of treatments applied following Gomez and Gomez (1984). Wherever, the F values were found significant at 5 percent levels of probability, the critical difference (CD) values were computed for making comparison among the treatment means.

In the case of weed management treatments, weed count was expressed as number per square metre and the data were subjected to $\sqrt{X} + 0.5$ transformation to normalise their distribution (Gomez and Gromez, 1984).

EXPERIMENTAL FINDINGS

The results of the experiment entitled **"Evaluation of Maize (*Zea mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition"** was conducted in the Experimental Research Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during two consecutive *kharif* seasons of 2016 and 2017. The data related to the effect of different treatments on main crop and intercrops as well as their pooled data were statistically analyzed and presented in this chapter with the help of tables and figures, wherever necessary.

4.1 Effect of planting geometry and weed management on plant growth, yield attributes and grain yield of maize in the maize based intercropping system

4.1.1 Plant growth parameters of maize .

4.1.1.1 Plant height (cm)

Data on plant height of maize as influenced by planting geometry and weed management were recorded at 30, 60 and 90 DAS in both the years *i.e. kharif*, 2016, 2017 and their pooled data calculated. The data on plant height of maize were presented in Table 4.1 and graphically depicted as Fig 4.1 & 4.2.

a) Effect of planting geometry

The study found that there was no significant effect on plant height of maize at 30 DAS by planting geometry in both the years as well as in pooled data. At 60 and 90 DAS, plant height of maize was significantly affected by planting geometry in both the years as well as in pooled data. Among the different planting geometry, maize + soybean (2:2) was found to have significant effect on the plant height of maize followed by maize + black gram (2:2).

The pooled data showed that planting geometry of maize + soybean (2:2) recorded the maximum plant height of 181.15 cm and 217.66 cm at 60 and 90 DAS respectively followed by maize + black gram (2:2) with 179.13 cm and 214.27 cm at 60 and 90 DAS respectively.

The increase in plant height of maize in intercropping might be due to better competition of maize with intercropped legumes for light, space and nutrients. Hefni *et al*. (1984) reported the increase of maize plant height when intercropped with soybean. Similarly, Mutnal and Hosmani (1985) also reported an increase in height of maize plant due to intercropping with legumes.

b) Effect of weed management

Weed management had significant affect on the plant height of maize in both the years of experimentation and pooled data as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the plant height of maize followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other but significantly superior over weedy check in effecting the maize plant height. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum plant height of 56.72 cm, 186.61 cm and 223.12 cm at 30, 60 and 90 DAS respectively. Weed management with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS effect the maize plant height with 55.82 cm, 184.61 cm and 220.13 cm at 30, 60 and 90 DAS respectively. Significantly lower plant height of maize with 48.48 cm, 164.02 cm and 195.06 cm were observed under weedy check at all stages of observation.

There was significant increase in plant height due to two hand weeding at 20 and 40 DAS. This increase in maize plant height might be due to reduced crop weed competition for plant growth factors such as light, space and nutrients. The lowest maize plant height was recorded in weedy check in both the years. It might be due to heavy crop-weed competition. These results were found to be in close conformity with the findings of Shinde *et al*. (2001) and Arvadia *et al*. (2012).

c) Interaction effect on plant height

The interaction effect of planting geometry and weed management practices in the present studies did not show any significant effect on plant height of maize at 30, 60 and 90 DAS in both the years as well as pooled data.

4.1.1.2 Number of leaves plant^{-1}

The data on number of leaves plant^{-1} were presented in Table 4.2 and depicted as Fig 4.3.

a) Effect of planting geometry

The study found that there was no significant effect on number of leaves plant^{-1} at 30, 60 and 90 DAS by different planting geometry in both the years and pooled data.

b) Effect of weed management

Weed management treatments significantly affected the number of leaves plant^{-1} in both the years of experimentation and pooled data as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the number of leaves plant^{-1} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were at par with each other statistically. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum number of leaves plant^{-1} as 9.23, 13.88 and 14.53 at 30, 60 and 90 DAS respectively. Weed management practice with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS effected the number of leaves plant^{-1} as 9.03, 13.31 and 13.81 at 30, 60 and 90 DAS respectively. The lowest number of leaves plant^{-1} of maize as 8.18, 11.99 and 12.40 were observed under weedy check at all stages of observation.

The number of leaves plant^{-1} was significantly influenced due to different weed management treatments at 30, 60 and 90 DAS. More number of leaves were recorded with two hand weeding at 20 and 40 DAS that might be due to proper weed management treatments thereby resulted into less weed competition for nutrient, sunlight, space and water. Similar results were also reported by Shinde *et al*. (2001) and Arvadia *et al*. (2012).

c) Interaction effect on number of leaves plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of leaves plant^{-1} at 30, 60 and 90 DAS in both years as well as pooled data.

4.1.1.3 Stem diameter (cm)

The data on stem diameter were presented in Table 4.3 and depicted as Fig 4.4.

a) Effect of planting geometry

The study found that there was no significant effect on stem diameter at 30, 60 and 90 DAS by planting geometry in both the years as well as in pooled data

b) Effect of weed management

All weed management practices had significant affect on stem diameter in both the years of experimentation as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on stem diameter followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were statistically at par with each other. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum size of stem diameter as 1.41 cm, 1.72 cm and 1.83 cm at 30, 60 and 90 DAS respectively. Weed management treatment with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS effected the size of stem diameter as 1.40 cm, 1.71 cm and 1.80 cm at 30, 60 and 90 DAS respectively. Significantly small size of stem diameter of maize as 1.21 cm, 1.50 cm and 1.60 cm were recorded under weedy check at all the stages of observation.

The size of stem diameter was significantly influenced due to different weed control treatments at 30, 60 and 90 DAS. The increased size of stem diameter might be due to better growth and development of the crop with reduced crop weed competition.

c) Interaction effect on stem diameter

The interaction effect of planting geometry and weed management practices did not show any significant effect on stem diameter at 30, 60 and 90 DAS in both the years as well as pooled data.

4.1.1.4 Leaf area index (LAI)

The data on leaf area index were presented in Table 4.4 and depicted as Fig 4.5 & 4.6.

a) Effect of planting geometry

The study found that there was no significant effect on LAI at 30 DAS by planting geometry in both the years as well as in pooled data. At 60 and 90 DAS, LAI was significantly affected by planting geometry in both the years as well as in pooled data. The pooled data showed that maize + soybean (2:2) recorded the maximum LAI of 3.38 and 3.50 at 60 and 90 DAS respectively followed by maize + black gram (2:2) as 3.32 and 3.43 at 60 and 90 DAS respectively. The significantly higher LAI in 2:2 planting geometry might be due to better spatial plant row arrangement that resulted into less competition in plant growth factors such as nutrient, sunlight, space, water etc. Prasad and Brook (2005) reported significant effect on LAI in maize + soybean intercropping. Shekhawat *et al.* (2002) and Rahimi *et al*. (2017) also reported significant increase of LAI in maize + black gram intercropping.

b) Effect of weed management

Among the weed management practices, two hand weeding at 20 and 40 DAS proved to have significant effect on LAI followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other. The pooled data of two hand weeding at 20 and 40 DAS recorded the LAI of 1.29, 3.67 and 3.82 at 30, 60 and 90 DAS respectively. Weed management treatment with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS effected the LAI as 1.27, 3.58 and 3.69 at 30, 60 and 90 DAS respectively. A small LAI of maize as 1.11, 2.64 and 2.72 were recorded under weedy check at all the respective stages of observation. The significant increase in LAI might be due to less weed competition for nutrient, sunlight, space, water etc. and thus resulted into better plant growth and development. Similar results were also reported by Arvadia *et al*. (2012).

c) Interaction effect on leaf area index

The interaction effect of planting geometry and weed management practices did not show any significant effect on LAI at 30, 60 and 90 DAS in both the years as well as pooled data.

4.1.2 Phenological observations on maize

4.1.2.1 Days to 50 % tasseling

Data on days to 50% tasseling of maize as influenced by planting geometry and weed management was recorded in both the years *i.e.* during *kharif*, 2016 and 2017. Their pooled data calculated and presented in Table 4.5.

a) Effect of planting geometry on days to 50% tasseling

It was evident from the data that planting geometry failed to produce any significant effect on days to 50% tasseling in both the years as well as in pooled results of experimentation.

b) Effect of weed management on days to 50% tasseling

A perusal on the relevant data revealed that there was no significant difference among the weed management treatments on days to 50% tasseling in both the years as well as in pooled data.

c) Interaction effect on days to 50% tasseling

The interaction effect of planting geometry and weed management practices did not show any significant effect on days to 50% tasseling in both the years as well as pooled data.

4.1.2.2 Days to 50 % silking

Data on days to 50% silking of maize as influenced by planting geometry and weed management was recorded for both the years *i.e. kharif*, 2016 and 2017 and their pooled data calculated. The data was presented in Table 4.5.

a) Effect of planting geometry on days to 50% silking

It was evident from the data that planting geometry failed to produce any significant effect on days to 50% silking in both the years as well as in pooled results of experimentation.

b) Effect of weed management on days to 50% silking

Weed management treatments did not show any significant influence on days to 50% silking in both the years as well as in pooled results of experimentation.

c) Interaction effect on days to 50% silking

The interaction effect of planting geometry and weed management practices did not show any significant effect on days to 50% silking in both the years as well as pooled data.

4.1.3 Yield Attributes of Maize

The yield attributes of maize *viz.*, number of cobs plant^{-1}, number of grain rows cob^{-1}, number of grains row^{-1} and 1000 grain weight (g) as influenced by different planting geometry and weed management treatments were presented and discussed as follows:

4.1.3.1 Number of cobs plant^{-1}

Data on number of cobs plant^{-1} of maize as influenced by planting geometry and weed management was recorded at harvest in both the years during *kharif*, 2016 and 2017 and presented in Table 4.6 and depicted as Fig 4.7 & 4.8.

a) Effect of planting geometry

The study found that there was no significant effect on number of cobs plant^{-1} by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

The number of cobs plant^{-1} was significantly influenced by weed management treatments as compared to weedy check in both the years and pooled data. Among the weed management practices, two hand weeding at 20 and 40 DAS proved to have significant effect on the number of cobs plant^{-1} (1.30) followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS (1.25). Less number of cobs plant^{-1} of maize *i.e.* 1.0 cob plant^{-1} was observed under weedy check. The probable reason for the highest number of cobs plant^{-1} under two hand weeding at 20 and 40 DAS might be due to better weed suppression and thus resulted into reduced crop weed competition upto a minimum level at critical growth stages of crop. Similar results were also reported by Haque *et al*. (2016). The lowest number of cobs plant^{-1} of maize under weedy check might have been resulted due to more crop weed competition. The present results supported the earlier reports of Dwivedi and Shrivastava (2011).

c) Interaction effect on number of cobs plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of cobs plant^{-1} in both the years as well as pooled data.

4.1.3.2 Number of grain rows cob^{-1}

Data on number of grain rows cob^{-1} of maize as influenced by planting geometry and weed management was recorded at harvest in both the years *i.e. kharif*, 2016 and 2017 and presented in Table 4.6 and depicted as Fig 4.7 & 4.8.

a) Effect of planting geometry

The present study found that there was no significant effect on number of grain rows cob^{-1} by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

All weed management treatments significantly effected the number of grain rows cob^{-1} in both the years of experimentation and pooled data as compared to weedy check. Among the weed management practices two hand weeding at 20 and 40 DAS proved to have significant effect on the number of grain rows cob^{-1} (12.58) followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one hand weeding at 30 DAS (12.24). Both the treatments were at par with each other. Significantly less number of grain rows cob^{-1} of maize *i.e.* 10.81 was recorded under weedy check. It might be due to better growth and development of plants under different weed management treatments. Lowest number of grain rows cob^{-1} of maize under weedy check might be due to more crop weed competition. Similar results were also reported by Dwivedi and Shrivastava (2011).

c) Interaction effect of grain rows cob^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of grain rows cob^{-1} in both the years *i.e. kharif*, 2016 and 2017 as well as pooled data.

4.1.3.3 Number of grains row^{-1}

Data on number grains row^{-1} of maize cob as influenced by planting geometry and weed management was recorded at harvest in both the years during *kharif*, 2016 and 2017 and presented in Table 4.6 and depicted as Fig 4.7 & 4.8.

a) Effect of planting geometry

The number of grains row^{-1} was significantly influenced by planting geometry in both the years as well as pooled data. The pooled data showed the highest number of grains row^{-1} in maize + soybean (2:2) as 28.12 which was at par with maize + black gram (2:2) as 27.92. It might be due to better growth and development of plants as a result of adequate special arrangement of row spacing. The present results were in agreement with the finding of Rahimi *et al*. (2017).

b) Effect of weed management

All weed management practices significantly increased the number of grains row^{-1} of maize cob in both the years of experimentation and pooled data as compared to weedy check. Among the weed management practices, two hand weeding at 20 and 40 DAS proved to have significant effect on the number of grains row^{-1} (28.85) followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS (28.53). Both the treatments were statistically at par with each other. Significantly less number of grains row^{-1} of maize *i.e.* 25.57 was observed under weedy check. The lowest number of grains row^{-1} of maize cob under weedy check might be due to more crop weed competition. Similar results were also reported by Dwivedi and Shrivastava (2011) and Haque *et al*. (2016).

c) Interaction effect on number of grains row^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of grains row^{-1} in both the years as well as pooled data.

4.1.3.4 1000 grain weight (g)

Data on 1000 grain weight as influenced by planting geometry and weed management was recorded in both the years *i.e. kharif*, 2016 and 2017 and pooled data and presented in Table 4.6.

a) Effect of planting geometry

It was evident from the data that planting geometry failed to produce any significant effect on 1000 grain weight in both the years as well as in pooled results of experimentation.

b) Effect of weed management

A perusal of data showed that 1000 grain weight was not significantly affected by weed management treatments as compared to weedy check in both the years and pooled data.

c) Interaction effect on grain weight

The interaction effect of planting geometry and weed management practices did not show any significant effect on grain weight in both the years as well as pooled data.

4.1.4 Yield

4.1.4.1 Grain yield (kg ha^{-1})

The data pertaining to grain yield were presented in Table 4.7 & 4.8 and illustrated as Fig 4.9 & 4.10.

a) Effect of planting geometry

The grain yield of maize was significantly influenced by planting geometry in both the years as well as pooled data. The pooled data showed the highest grain yield of maize in maize + soybean (2:2) as 2565.96 kg ha^{-1} which was statistically at par with maize + black gram (2:2) as 2505.12 kg ha^{-1}. The lowest grain yield was recorded in maize + black gram (1:1) as 2305.6 kg ha^{-1}.

The reason for maximum grain yield in paired row planting might be due to decreased competition between plants because of better spatial arrangement of plants. Similar findings were also reported by Maitra *et al*. (2000). Kithan and Longkumer (2014) also reported that the maize + soybean 2:2 ratio was superior in respect of both maize and soybean yield due to suitable combination of row ratio for efficient utilization of natural resources and benefit associated with atmospheric fixation by the soybean crop. This observation got support from the results reported by Buriro *et al*. (1991). The maximum reduction of maize yield was recorded in the planting geometry under maize + black gram (1:1) due to more interspecific competition. Similar finding was also reported by Singh *et al*. (2008).

b) Effect of weed management

The grain yield of maize was significantly increased by weed management treatments as compared to weedy check in both the years and pooled data. The pooled data showed that the highest grain yield of maize was recorded in two hand weeding at 20 and 40 DAS as 2851.33 kg ha^{-1} which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW 30 DAS as 2779.83. The lowest grain yield was recorded in weedy check *i.e.* 1699.05 kg ha^{-1}.

Shekhawat *et al*. (2002) was of the opinion that the increase in maize grain yield might be due to reduced weed competition as well as cumulative increase in growth characters due to favourable conditions created under weed free conditions. Similar results were also reported by Thakur *et al*. (1989). The grain yield of maize in weedy check was severely reduced due to more crop weed competition. Similar result was also reported by Dwivedi and Shrivastava (2011). Reduction in grain yield of weedy check might have caused by reduced growth and yield components of maize under increased pressure of weed competition for space, light, nutrients etc. (Haque *et al*., 2013).

c) Interaction effect on grain yield kg ha^{-1}

The interaction effect of planting geometry and weed management practices on grain yield of maize was found to have significant effect in both the years as well as pooled data. The pooled data showed that the highest grain yield (3000.67 kg ha^{-1}) was recorded under the treatment combination of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS which was statistically at par with treatment combination of maize + black gram (2:2) with two hand weeding at 20 and 40 DAS (2936.95 kg ha^{-1}). The lowest grain yield of maize 1638.98 kg ha^{-1} was obtained under the treatment combination of maize + black gram (1:1) with weedy check.

The probable reason for higher grain yield in paired row planting with two hand weeding at 20 and 40 DAS might be due to the cumulative effects of better plant growth, higher values of yield attributes resulted from better arrangement of row spacing, adequate weed control and better utilization of natural resources. Rahimi *et al.* (2017) also reported significant interaction effects of intercropping systems and weed management practices on grain yield of maize.

4.1.4.2 Stover yield (kg ha^{-1})

Data on stover yield as influenced by planting geometry and weed management in both the years were recorded and pooled data calculated and presented in Table 4.7 & 4.8 and their graphical representations were depicted as Fig 4.9 & 4.10.

a) Effect of planting geometry

The stover yield showed significant difference due to planting geometry in both the years and pooled data. The data showed that the highest stover yield was recorded by maize + soybean (2:2) as 5043.59 kg ha^{-1} which was at par with maize + black gram (2:2) as 4946.68 kg ha^{-1}. The lowest stover yield was recorded in maize + black gram (1:1) *i.e.* 4566.22 kg ha^{-1}. This might be due to higher plant growth parameters along with better utilization of the available natural resources. Shivay *et al.* (2002) also reported that intercrop of soybean or black gram had a beneficial effect on stover yield of maize.

b) Effect of weed management

The stover yield of maize was significantly increased by weed control treatments as compared to weedy check in both the years and pooled data. The pooled data showed that the highest stover yield was recorded by two hand weeding at 20 and 40 DAS as 5525.38 kg ha^{-1} which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW 30 DAS as 5400.71 kg ha^{-1}. The lowest stover yield was recorded in weedy check *i.e.* 3556.74 kg ha^{-1}.The increased stover yield might be the result of better weed control which gave favourable conditions like increased availability of nutrients, moisture, light, etc. Shivakumar and Devaranavadagi (2017) also reported that weed free check recorded higher stover yield.

c) Interaction effect on stover yield kg ha^{-1}

The interaction effect of planting geometry and weed management practices had significant effect on stover yield kg ha^{-1} in both the years as well as pooled data. The pooled data showed that treatment combination of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS recorded the maximum stover yield as 5793.98 kg ha^{-1} which was at par with maize + black gram (2:2) with two hand weeding at 20 and 40 DAS as 5686.68 kg ha^{-1}. Rahimi *et al.* (2017) also reported significant interaction effects of intercropping systems and weed management practices on stover yield of maize.

4.1.4.3 Maize equivalent yield (MEY) kg ha^{-1}

The data on maize equivalent yield as affected by planting geometry and weed management of maize intercropped with black gram and soybean were presented in Table 4.7 & 4.8 and their graphical representations were depicted as Fig 4.9 & 4.10.

a) Effect of planting geometry

The study found that there was significant effect on maize equivalent yield by planting geometry in both the years as well as in pooled data. As per the pooled data, the highest maize equivalent yield was recorded from maize + soybean (2:2) as 4374.96 kg ha^{-1} followed by maize + soybean (1:1) as 4165.55 kg ha^{-1}. This increase in total production of maize with soybean intercropping was the result of additional yield of soybean as bonus by utilization of inter-row space of maize crops. Similar results were also reported by Padhi and Panigrahi (2006). The present results were in general agreement with the earlier result reported by Kheroar and Patra (2014).

b) Effect of weed management

Weed management treatments were significantly different in terms of maize equivalent yield for both the years of experimentation and their pooled data. Weed management treatment of two hand weeding at 20 and 40 DAS recorded the highest maize equivalent yield of 4591.10 kg ha^{-1} followed by application of pendimethalin pre-emergence @ 1.0 kg a.i.ha^{-1} with one hand weeding at 30 DAS as 4461.80 kg ha^{-1}. The reason for increase in maize equivalent yield under two hand weeding at 20 and 40 DAS might be due to reduced crop-weed competition during critical phase of crop growth. The present findings were in conformity with the earlier reports made by Patel *et al*. (2015a).

c) Interaction effect on maize equivalent yield kg ha^{-1}

The interaction effect of planting geometry and weed management practices had significant effect on maize equivalent yield in both the years as well as pooled data. The pooled data showed that the treatment combination of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS recorded the maximum maize equivalent yield as 5055.30 kg ha^{-1} which was at par with maize + soybean (1:1) with two hand weeding at 20 and 40 DAS as 4800.51 kg ha^{-1}.

4.2 Effect of planting geometry and weed management on plant growth, yield attributes and seed yield of black gram in maize based intercropping system

4.2.1 Plant growth parameters of black gram

Progressive crop growth parameters were recorded at different stages of crop growth *i.e.* 30, 60 days after sowing (DAS) and at harvest in both the years *i.e. kharif*, 2016 and 2017 and their pooled data were calculated.

4.2.1.1 Plant height (cm)

Data on plant height of black gram at different stages of crop growth as affected by planting geometry and weed management practices for both the years *i.e. kharif*, 2016 and 2017and pooled data were presented in Table 4.9 and depicted as Fig 4.11.

a) Effect of planting geometry

The study found that there was no significant effect on plant height at 30, 60 DAS and at harvest by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

All the weed management treatments significantly effected the plant height in both the years of experimentation and pooled data as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the plant height followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at

30 DAS. Both the treatments were observed to be statistically at par with each other. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum plant height as 17.20, 38.73 and 50.29 cm at 30, 60 DAS and at harvest respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 16.14, 36.65 and 48.33 cm at 30, 60 DAS and at harvest respectively. The shortest plant height of black gram as 12.34, 30.74 and 41.05 cm were recorded at 30, 60 DAS and at harvest respectively with weedy check.

Higher plant height of black gram under two hand weeding at 20 and 40 DAS might be due to lower crop weed competition and better utilization of natural resources. Singh *et al.* (1998) reported that the highest mean plant height of black gram was recorded under two hand weeding and hoeing at three and five weeks after sowing. Shekhawat *et al.* (2002) was of the opinion that maximum plant height in legume crops was obtainable under weed free treatment.

c) Interaction effect on plant height

The interaction effect of planting geometry and weed management practices did not show any significant effect on plant height at 30, 60 DAS and at harvest in both the years as well as pooled data.

4.2.1.2 Number of branches $plant^{-1}$

Data on number of branches $plant^{-1}$ of black gram as influenced by planting geometry and weed management were presented in Table 4.10 and depicted as Fig 4.12.

a) Effect of planting geometry

The study found that there was no significant effect on number of branches plant^{-1} at 30, 60 DAS and at harvest by planting geometry during *kharif*, 2016 and 2017 as well as in pooled data.

b) Effect of weed management

All the weed management treatments showed significant effect on number of branches plant^{-1} in both the years of experimentation and pooled data as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to be significantly effective in increasing the number of branches plant^{-1} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other but significantly superior over weedy check. The pooled data showed that two hand weeding at 20 and 40 DAS had the maximum number of branches plant^{-1} as 2.23, 3.03 and 3.68 at 30, 60 DAS and at harvest respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 2.03, 2.87 and 3.45 at 30, 60 DAS and at harvest respectively. The lowest number of branches plant^{-1} of black gram were recorded with weedy check as 1.43, 2.20 and 2.77 at the respective stages of observation.

The highest number of branch under two hand weeding at 20 and 40 DAS might be due to the lower crop weed competition in regard with the utilization of nutrients, moisture, light, space, etc.

c) Interaction effect on number of branches plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant difference on number of branches plant^{-1} at 30, 60 DAS and at harvest in both the years as well as pooled data.

4.2.1.3 Number of leaves plant^{-1}

Data on number of leaves plant^{-1} of black gram as influenced by planting geometry and weed management were presented in Table 4.11 and depicted as Fig 4.13.

a) Effect of planting geometry

The study found that there was no significant effect on number of leaves plant^{-1} at 30, 60 DAS and at harvest by planting geometry during *kharif*, 2016 and 2017 as well as in pooled data.

b) Effect of weed management

All the weed management treatments significantly effected number of leaves plant^{-1} during *kharif*, 2016 and 2017 and pooled data as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the number of leaves plant^{-1} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were statistically at par with each other but significantly superior over weedy check. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum number of leaves per plant as 10.10, 24.38 and 20.25 at 30, 60 DAS and at harvest respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 9.33, 23.15 and 19.23 at 30, 60 DAS and at harvest respectively. The lowest number of leaves plant^{-1} of black gram were recorded with weedy check as 7.17, 19.02 and 16.00 at all stages of observation. Significantly increased number of leaves plant^{-1} by two hand weeding at 20 and 40 DAS over weedy check might be due to lower crop weed competition for plant growth in respect of light, space, water, nutrients, etc.

c) Interaction effect on number of leaves plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant difference on number of leaves plant^{-1} at 30, 60 DAS and at harvest in both the years as well as pooled data.

4.2.1.4 Leaf area index (LAI)

Data on leaf area index of black gram as influenced by planting geometry and weed management practices were recorded at 30, 60 DAS and at harvest in both the years *i.e. kharif*, 2016 and 2017 and pooled data calculated. The data were presented in Table 4.12 and depicted as Fig 4.14.

a) Effect of planting geometry

The study found that there was no significant effect on LAI at 30, 60 DAS and at harvest by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

All the weed management treatments significantly effected LAI of black gram in both the years of experimentation as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on leaf area index followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum LAI as 0.53, 1.78 and 1.29 at 30, 60 DAS and at harvest respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 0.51, 1.68 and 1.24 at 30, 60 DAS and at harvest respectively. The minimum leaf area index of black gram as 0.43, 1.28

and 1.00 were observed under weedy check at the respective stages of observation. Increased LAI of black gram with two hand weeding at 20 and 40 DAS might be due to the lack of weed crop competition that improved the crop growth. Rao *et al*. (2015) was of the opinion that weed free conditions maintained with two hand weeding might have eliminated the crop weed competition for space, nutrient, moisture and light and thus the crop performed better. Further, it was also stated that absence of early weed crop competition increased the crop growth rate thereby increased plant leaf area index (Srivastava *et al*., 2003 and Tamang *et al*., 2015). Amini *et al*. (2013) also reported that the weed infested crop caused reduction in LAI in comparison with weed free treatment especially at the end of the growth.

c) Interaction effect on leaf area index

The interaction effect of planting geometry and weed management practices did not show any significant effect on LAI at 30, 60 DAS and at harvest in both the years as well as pooled data.

4.2.1.5 Number of nodules plant^{-1}

Data on number of nodules plant^{-1} of black gram as influenced by planting geometry and weed management during *kharif*, 2016 and 2017 as well as the pooled data were presented in Table 4.13 and depicted as Fig 4.15.

a) Effect of planting geometry

The study found that there was no significant effect on number of nodules plant^{-1} at 30 and 60 DAS by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

All the weed management treatments significantly effected the number of nodules plant^{-1} of black gram in both the years of experimentation as compared to weedy check. Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to be significantly effective in producing the number of nodules plant^{-1} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other but significantly superior over weedy check in effecting the number of nodules per plant. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum number of nodules plant^{-1} as 8.18 and 29.57 at 30 and 60 DAS followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 7.35 and 28.33 at 30 and 60 DAS respectively. Minimum number of nodules plant^{-1} of black gram as 4.73 and 24.42 were recorded under weedy check at 30 and 60 DAS.

The increase in number of effective nodules plant^{-1} might be attributed to the removal of weed competition in terms of allelopathy due to effective control of weeds. Weedy check gave the minimum number of nodules due to allelopathic effect caused by weed and reduced supply of energy from crop for fixation of atmospheric nitrogen as a result of reduced crop growth due to severe weed competition. Kundu *et al.* (2011) reported the maximum number of nodules with hand weeding in legume crops.

c) Interaction effect on number of nodules plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of nodules plant^{-1} at 30 and 60 DAS in both the years as well as pooled data.

4.2.2 Yield attributes of black gram

The yield attributes *viz.* number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight (g) as influenced by different planting geometry and weed management practices were recorded in both the years of experimentation and pooled data calculated.

4.2.2.1 Number of pods plant^{-1}

The data regarding pods plant^{-1} as influenced by planting geometry and weed management practices in both the years of experimentation were presented in Table 4.14 and illustrated as Fig 4.16.

a) Effect of planting geometry

It was evident from the data (Table 4.14) that planting geometry failed to produce any significant effect on number of pods plant^{-1} in both the years as well as in pooled data.

b) Effect of weed management

Effect of weed management treatments on number of pods plant^{-1} of black gram was found to be significant in both the years of experimentation and pooled data. The pooled data showed that the two hand weeding at 20 and 40 DAS produced the highest number of pods plant^{-1} of black gram (29.76) which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS (28.59). The lowest number of pods plant^{-1} was recorded in weedy check *i.e.* 22.05. Shekhawat *et al*. (2002) reported that weed free treatment resulted in maximum number of pods plant^{-1} in legumes.

c) Interaction effect on number of pods plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant difference on number of pods plant^{-1} in both the years as well as pooled data.

4.2.2.2 Number of seeds pod^{-1}

The data pertaining to number of seeds pod^{-1} were presented in Table 4.14 and illustrated as Fig 4.16.

a) Effect of planting geometry

The effect of planting geometry on number of seeds pod^{-1} was non significant in both the years of experimentation as well as pooled data.

b) Effect on weed management

Weed management treatments produced significant differences in seeds pod^{-1} of black gram in both the years and pooled data. The pooled data showed that the maximum number of seeds per pod was recorded by two hand weeding at 20 and 40 DAS as 5.65 which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 5.47. The lowest number of seeds pod^{-1} was recorded in weedy check as 4.67. The maximum number of seeds pod^{-1} in weed free treatment was also reported by Shekhawat *et al*. (2002).

c) Interaction effect on number of seeds pod^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of seeds pod^{-1} in both the years as well as pooled data.

4.2.2.3 1000 seed weight (g)

The data pertaining to 1000 seed weight was presented in Table 4.14.

a) Effect of planting geometry

The effect of planting geometry on 1000 seed weight was not significant in both the years of experimentation as well as pooled data.

b) Effect on weed management

The effect of weed management treatment on 1000 seed weight was not significant in both the years of experimentation as well as pooled data.

c) Interaction effect on 1000 seed weight

The interaction effect of planting geometry and weed management practices did not show any significant difference on 1000 seed weight in both the years as well as pooled data.

4.2.3 Yield of black gram

4.2.3.1 Seed yield (kg ha^{-1})

The seed yield of black gram for different planting geometry and weed management practices in both the years of experimentation *i.e. kharif*, 2016 and 2017 and their pooled data were presented in Table 4.15 and illustrated as Fig 4.17.

a) Effect of planting geometry on seed yield

The data on planting geometry did not show any significant difference on seed yield of black gram in both the years as well as pooled data.

b) Effect of weed management on seed yield

All the weed management treatments significantly increased the seed yield of black gram in both the years. The pooled data showed the highest seed yield of black gram with two hand weeding at 20 and 40 DAS as 389.22 kg ha^{-1} which was at par with pre-emergence application pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 376.02 kg ha^{-1}. The lowest seed yield of black gram was recorded in weedy check as 300.28 kg ha^{-1}.

The highest seed yield recorded with two hand weeding at 20 and 40 DAS followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS might be due to lesser crop-weed competition with these treatments as they control weeds effectively than other treatments. Such a similar result was also reported by Singh (2011). The weedy check recorded significantly minimum yield due to heavy competition for nutrient, moisture and light between the crop and weeds. Similar finding was also reported by Rao *et al.* (2010). Shekhawat *et al*. (2002) and Mallikarjuna *et al*. (2013) were of the opinion that weed free treatment resulted in maximum seed yield.

c) Interaction effect on seed yield

The interaction effect of planting geometry and weed management practices did not show any significant effect on seed yield in both the years as well as pooled data.

4.2.3.2 Stover yield (kg ha^{-1})

Data on stover yield of black gram as affected by various planting geometry and weed management in both the years of study were presented in Table 4.15 and depicted as Fig 4.17.

a) Effect of planting geometry

Table 4.15 showed that stover yield did not get any significant impact by planting geometry in both the years and pooled data.

b) Effect of weed management

Table 4.15 showed that stover yield was significantly increased by weed control treatments as compared to weedy check in both the years and pooled data. The pooled data showed the highest stover yield in two hand weeding at 20 and 40 DAS as 805.38 kg ha^{-1} which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW 30 DAS as 785.08 kg ha^{-1}. The lowest stover yield was recorded in weedy check as 656.03 kg ha^{-1}. Similar result of maximum stover yield in weed free treatments was also reported by Shekhawat *et al*. (2002).

c) Interaction effect on stover yield

The interaction effect of planting geometry and weed management practices did not show any significant effect on stover yield in both the years as well as pooled data.

4.3 Effect of planting geometry and weed management on plant growth, yield attributes and yield of soybean in maize based intercropping system

4.3.1 Plant growth parameters of soybean

Progressive crop growth and development were recorded at different stages of crop *i.e.* 30, 60 and 90 DAS. Effect of experimental variables on plant growth and development were presented and discussed hereunder.

4.3.1.1 Plant height (cm)

Data on plant height of soybean as influenced by planting geometry and weed management were recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and data were presented in Table 4.16 and depicted as Fig 4.18 .

a) Effect of planting geometry

The study found that there was no significant effect on plant height at 30, 60 and 90 DAS by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

Weed management treatments significantly effect the plant height in both the years of experimentation as compared to weedy check (Table 4.15). Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on plant height of soybean followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other and significantly superior over weedy check in effecting the plant height. The pooled data of two hand weeding at 20 and 40 DAS recorded the highest plant height as 27.76, 67.11 and 72.34 cm at 30, 60 and 90 DAS respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 26.63, 65.24 and 69.29 cm at 30, 60 and 90 DAS respectively. The shortest plant height of soybean as 22.35, 58.38 and 59.93 cm was recorded under weedy check at all the stages of observation. The maximum plant height which was recorded by two hand weeding at 20 and 40 DAS might be due to the increased availability of nutrients and lesser competition of weeds that could possibly result in better accumulation of photosynthesis. Similar results were also reported by Thakur (2008) and Dhane *et al*. (2010).

c) Interaction effect on plant height

The interaction effect of planting geometry and weed management practices did not show any significant effect on plant height at 30, 60 and 90 DAS in both the years as well as pooled data.

4.3.1.2 Number of branches plant^{-1}

Data on number of branches plant^{-1} of soybean as influenced by planting geometry and weed management was recorded at 30, 60 and at 90 DAS in both the years during *kharif*, 2016 and 2017 and presented in Table 4.17 and Fig 4.19.

a) Effect of planting geometry

The study found that there was no significant effect on number of branches plant^{-1} at 30, 60 and 90 DAS by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

Weed management treatments significantly increased the number of branches plant^{-1} in both the years of experimentation as compared to weedy check (Table 4.17). Among the weed management practices, hand weeding at 20 and 40 DAS proved to have significant effect on the number of branches plant^{-1} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were statistically at par with each other and significantly superior over weedy check in increasing the number of branches plant^{-1}. The pooled data showed that hand weeding at 20 and 40 DAS recorded the maximum number of branches plant^{-1} as 1.77, 4.43

and 4.55 at 30, 60 and 90 DAS respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.63, 4.25 and 4.40 at 30, 60 and 90 DAS respectively. The lowest number of branches $plant^{-1}$ of soybean as 1.20, 2.95 and 3.25 were observed under weedy check at all stages of observation.

The highest number of branches recorded from two hand weeding at 20 and 40 DAS might be due to lack of crop weed competition resulting into better utilization of nutrients, moisture, light and space by the crop. Bali *et al*. (2016) reported the maximum number of branches $plant^{-1}$ in weed free conditions which was statistically at par with hand weeding at 15 and 35 DAS.

c) Interaction effect on number of branches $plant^{-1}$

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of branches $plant^{-1}$ at 30, 60 and 90 DAS in both the years as well in pooled data.

4.3.1.3 Number of leaves $plant^{-1}$

Data on number of leaves $plant^{-1}$ of soybean as influenced by planting geometry and weed management was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and presented in Table 4.18 and depicted as Fig 4.20.

a) Effect of planting geometry

The study showed that there was no significant effect on number of leaves at 30, 60 and 90 DAS by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

Weed management treatments had significant effect on the number of leaves plant^{-1} in both the years of experimentation as compared to weedy check (Table 4.18). Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the number of leaves per plant followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were observed to be at par with each other and significantly superior over weedy check in increasing the number of leaves plant^{-1}. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the number of leaves plant^{-1} as 9.00, 21.13 and 25.07 at 30, 60 and 90 DAS respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 8.48, 20.10 and 24.15 at 30, 60 and 90 DAS respectively. The minimum number of leaves plant^{-1} of soybean as 6.75, 16.07 and 19.78 were recorded under weedy check at all stages of observation. The maximum number of leaves under two hand weeding at 20 and 40 DAS might be due to reduced crop weed competition and better utilization of available resources like moisture, nutrients and more space for the plant growth.

c) Interaction effect on number of leaves plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of leaves plant^{-1} at 30, 60 and 90 DAS in both the years as well as pooled data.

4.3.1.4 Leaf area index (LAI)

Data on leaf area index of soybean as influenced by planting geometry and weed management was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and presented in Table 4.19 and depicted as Fig 4.21.

a) Effect of planting geometry

The study found that there was no significant effect on LAI at 30, 60 and 90 DAS as influenced by planting geometry in both the years as well as in pooled data.

b) Effect of weed management

Weed management treatments significantly effected LAI of soybean in both the years of experimentation as compared to weedy check (Table 4.19). Among the weed management treatments, two hand weeding at 20 and 40 DAS proved to have significant effect on the leaf area index followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Both the treatments were statistically at par with each other and significantly superior over weedy check. The pooled data showed that two hand weeding at 20 and 40 DAS recorded the maximum LAI as 0.77, 1.77 and 1.83 at 30, 60 and 90 DAS respectively followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 0.73, 1.71 and 1.77 at 30, 60 and 90 DAS respectively. The minimum LAI of soybean as 0.53, 1.49 and 1.54 were observed under weedy check at all stages of observation.

c) Interaction effect on leaf area index

The interaction effect of planting geometry and weed management practices did not show any significant effect on leaf area index at 30, 60 and 90 DAS in both the years as well in pooled data.

4.3.1.5 Number of nodules plant^{-1}

The data on periodic number of nodules plant^{-1} were presented in Table 4.20 and graphically depicted as Fig 4.22.

a) Effect of planting geometry

Planting geometry did not produce any significant effect on the number of nodules plant^{-1} of soybean at 30 and 60 in both the years as well as pooled data.

b) Effect of weed management

Weed management treatments had significant effect on number of nodules plant^{-1} of soybean at 30 and 60 DAS during *kharif*, 2016 and 2017 and their pooled data. The pooled data showed that two hand weeding at 20 and 40 DAS produced the highest nodules as 4.37 and 36.18 at 30 and 60 DAS respectively which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 3.92 and 34.73 at 30 and 60 DAS and the lowest number of nodules plant^{-1} was recorded in weedy check as 2.65 and 25.73 at 30 and 60 DAS respectively. It was observed that number of nodules plant^{-1} increased up to 60 DAS and thereafter nodule production decreased. Among the weed management treatments, two hand weeding at 20 and 40 DAS recorded significantly higher number of nodules plant^{-1}. This increase in number of effective nodules per plant was mainly attributed to removal of weed competition in terms of allelopathy due to effective control of weeds. While, weedy check recorded significantly lower number of effective nodules per plant due to allelopathic effect caused by weeds and also due to reduced supply of energy from crop for fixation of atmospheric nitrogen as a result of reduced crop growth due to severe weed competition. Selvam *et al*. (1999) reported that hand weeding twice had the highest number of root nodules plant^{-1}.

c) Interaction effect on number of nodules plant^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant difference effect on number of nodules plant^{-1} at 30 and 60 DAS in both the years as well as pooled data.

4.3.2 Yield Attributes of Soybean

The yield attributes *viz.* number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight (g) as influenced by different planting geometry and weed management practices were presented and discussed hereunder:

4.3.2.1 Number of pods plant^{-1}

The data regarding pods plant^{-1} as influenced by planting geometry and weed management treatments in both the years of experimentation and their pooled data were presented in Table 4.21 and graphically illustrated as Fig 4.23.

a) Effect of planting geometry

It was evident from the data that planting geometry failed to produce any significant effect on number of pods plant^{-1} in both the years as well as in pooled data of experimentation.

b) Effect of weed management

Effect of weed management treatments on number of pods plant^{-1} of soybean was significantly increased by weed control treatments as compared to weedy check in both the years as well as in pooled data. The pooled data showed that the maximum number of pods plant^{-1} was recorded with two hand weeding at 20 and 40 DAS as 50.98 which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 48.03. The minimum number of pods $plant^{-1}$ was recorded in weedy check *i.e.* 36.63. The maximum number of pods $plant^{-1}$ with two hand weeding at 20 and 40 DAS might be due to increased plant growth resulted from minimum crop weed competition with optimum utilization of different resources such as soil moisture, nutrient and solar radiation. Jain *et al.* (1998) also reported significantly higher number of pods of soybean $plant^{-1}$ with two hand weeding.

c) Interaction effect on number of pods $plant^{-1}$

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of pods $plant^{-1}$ in both the years as well as pooled data.

4.3.2.2 Number of seeds pod^{-1}

The data regarding seeds pod^{-1} as influenced by planting geometry and weed management practices in both the years of experimentation and their pooled data were presented in Table 4.21 and illustrated as Fig 4.23.

a) Effect of planting geometry

The effect of planting geometry on number of seeds pod^{-1} was found to be non significant in both the years of experimentation as well as in pooled data.

b) Effect of weed management

A perusal of data showed that number of seeds pod^{-1} was significantly increased by weed control treatments as compared to weedy check in both the years as well as in pooled data. The pooled data showed that the highest number of seeds pod^{-1} of soybean was recorded with two hand weeding at 20 and 40 DAS as 2.80 which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 2.67. The lowest number of seeds pod^{-1} was recorded in weedy check as 2.20. The probable reason for higher number of seeds pod^{-1} under two hand weeding at 20 and 40 DAS might be due to better weed suppression that resulted into reduced crop weed competition and thus facilitated better crop growth. Haque *et al*. (2016) reported the highest number of seed pod^{-1} in the treatment that received three hand weeding.

c) Interaction effect on number of seed pod^{-1}

The interaction effect of planting geometry and weed management practices did not show any significant effect on number of seeds pods^{-1} in both the years as well as in pooled data.

4.3.2.3. 1000 seed weight (g)

The data regarding 1000 seed weight as influenced by planting geometry and weed management practices in both the years of experimentation were presented as Table 4.21.

a) Effect of planting geometry

The effect of planting geometry on 1000 seed weight was non significant in both the years of experimentation as well as in pooled data.

b) Effect of weed management

The effect of weed management treatment on 1000 seed weight was non significant in both the years of experimentation as well as in pooled data.

c) Interaction effect on 1000 seed weight

The interaction effect of planting geometry and weed management practices did not show any significant effect on 1000 seed weight in both the years as well as in pooled data.

4.3.3 Yield of soybean

4.3.3.1 Seed yield (kg ha^{-1})

Data on seed yield as influenced by planting geometry and weed management was recorded in both the years. The year wise mean data and pooled data for both the years were presented in Table 4.22 and graphically depicted as Fig 4.24.

a) Effect of planting geometry

A perusal of data showed that seed yield of soybean was not significantly influenced different by planting geometry in both the years and in pooled data.

b) Effect of weed management

Weed management treatments significantly increased seed yield of soybean as compared to weedy check in both the years and pooled data. The pooled data showed that among weed management treatments the highest seed yield of soybean was recorded with two hand weeding at 20 and 40 DAS as 969.53 kg ha^{-1} which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 937.79 kg ha^{-1}. The lowest seed yield was recorded in weedy check as 657.31 kg ha^{-1}. The higher seed yield in the above treatments might be due to effective control of weeds during the early stages of crop growth that helped in better development of the plant through less competition for nutrients, solar radiation and water from weeds. Similar results were also reported by Rao *et al*. (1995), Pandya *et al*. (2006) and Kamdi (2010). Haque *et al*. 2016 reported higher yield of soybean in the treatments receiving three hand weeding.

c) Interaction effect on seed yield

The interaction effect of planting geometry and weed management treatments did not show any significant effect on seed yield of soybean in both the years as well as in pooled data.

4.3.3.2 Stover yield (kg ha^{-1})

Data on stover yield of soybean as affected by various planting geometry and weed management treatments in both the years and their pooled data were presented in Table 4.22 and depicted as Fig 4.24.

a) Effect of planting geometry

The stover yield of soybean was not significantly influenced by planting geometry in both years and pooled data.

b) Effect of weed management

All the weed management treatments significantly increased stover yield of soybean as compared to weedy check in both the years and pooled data. The pooled data showed that the highest stover yield of soybean was recorded with two hand weeding at 20 and 40 DAS as 2064.87 kg ha^{-1} which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 2012.28 kg ha^{-1}. The lowest stover yield of soybean was recorded in weedy check as 1503.53 kg ha^{-1}. The increase in stover yield of soybean might have resulted from better weed control under two hand weeding at 20 and 40 DAS and increased availability of nutrients due to better crop weed competition. Patel *et al*. (2018) reported the higher stover yield of soybean after one hoeing at 15 DAS and 2 HW at 25 and 45 DAS. Bali *et al*. (2016) also reported that the maximum stover yield was obtained with weed free treatment and hand weeding at 15 and 35 DAS.

c) Interaction effect on stover yield

The interaction effect of planting geometry and weed management treatments did not show any significant effect on stover yield in both the years as well as in pooled data.

4.4 Weed studies as effected by planting geometry and weed management in the maize based intercropping system

4.4.1 Weed population studies

I. Monocot weed population

The data regarding monocot weed population as influenced by planting geometry and weed management at 30 days interval was recorded at 30, 60 and 90 DAS in both the years of studies during *kharif*, 2016 and 2017 and their pooled data calculated. The data were presented in Table 4.24 and 4.25 and graphically depicted as Fig 4.25 & 4.26. The list of monocot weed species available in the experimental plot was presented in Table 4.23(a).

a) Effect of planting geometry

At 30 DAS, different planting geometry did not significantly influence the monocot weed population in both the years as well as in pooled results.

The influences of different planting geometry on monocot weed population were significant at 60 and 90 DAS in both the years as well as in pooled data. Pooled data indicated that significantly least population of weed were recorded in maize + soybean (2:2) as 98.13 and 85.21 m^{-2} which was closely followed by 102.40 and 88.43 m^{-2} with maize + black gram (2:2) at 60 and 90 DAS respectively. The maximum population of monocot weed density of 114.99 and 99.47 m^{-2} were recorded at 60 and 90 DAS respectively in maize + black gram (1:1).

Planting geometry of maize + soybean (2:2) proved to be significantly superior to other treatments in the reduction of monocot weed population (Table 4.24). Therefore, maize + soybean (2:2) were more effective in controlling monocot weeds. This might be due to relatively less space available for the growth of weeds due to quick coverage of ground and more shading effect by maize and soybean intercropping. Similar effects due to planting pattern were also reported by Prasad and Rafey (1996), Deshveer and Singh (2002) and Pandey *et al.* (2003). The increased population of crop species per unit area and crop competition in intercropping might also be the possible reason for effective weed control (Jayaraj, 1991).

b) Effect of weed management

All the weed management treatments significantly influenced the monocot weed population density at 30, 60 and 90 DAS in both the years as well as in pooled data. The pooled data showed that weedy check produced the highest monocot weed population density as 150.27, 235.93 and 209.32 m^{-2} at 30, 60 and 90 DAS respectively. Two hand weeding treatment at 20 and 40 DAS was recorded significantly lower monocot weed population density as 25.30, 33.20 and 30.20 m^{-2} at 30, 60 and 90 DAS respectively which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 33.24,51.67 and 37.57 m^{-2} at 30, 60 and 90 DAS.

Considerable reduction in weed population due to two hand weeding at 20 and 40 DAS and pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS might be probably due to better weed control in critical stages of crop growth through hand weeding and phytotoxic effect of chemicals on broad spectrum of weeds resulting into the death of most of the weeds. The herbicides gave almost season long control of weeds due to their persistence in soil for a sufficiently long time. The results were in conformity with the earlier reports made by Yaduraju *et al*. (1986) and Prasad and Srivastava (1990).

c) Interaction effect on monocot weed population

The interaction effects of planting geometry and weed management treatments on monocot weed population at 60 and 90 DAS were found to have significant effect in both the years as well as in pooled data. At 60 and 90 DAS, maize + soybean (2:2) planting geometry combined with two hand weeding at 20 and 40 DAS recorded minimum monocot weed population of 27.20 and 24.02 m^{-2} respectively which were statistically at par with monocot weed population of 29.43 and 26.98 m^{-2} respectively in maize + black gram (2:2) combined with two hand weeding at 20 and 40 DAS.

II. Dicot weed population

The data of dicot weed population as influenced by planting geometry and weed management at 30 days interval were recorded at 30, 60 and 90 DAS for both the years during *kharif*, 2016 and 2017 and their pooled data calculated. The data were presented in Table 4.26 & 4.27 and graphically depicted as Fig 4.27 & 4.28. The list of dicot weed species available in the experimental plots was presented as Table 4.23(b).

a) Effect of planting geometry

Different planting geometry did not significantly influence the dicot weed population at 30 DAS in both the years as well as in pooled data.

The effect of different planting geometry in dicot weed population density was found to be statistically significant at 60 and 90 DAS in both the years and in pooled data. The pooled data showed that planting geometry maize + soybean (2:2) at 60 and 90 DAS recorded the lowest dicot weed population density as 17.92 and 8.26 m^{-2} respectively followed by maize + black gram (2:2) as 18.97 and 8.94 m^{-2} respectively. The two treatments were found to be statistically at par with each other at 60 and 90 DAS. The reduction in weed density in intercropping systems might be attributed to shading effect and competition stress created by the canopy of more crops in an unit area having suppressive effect on associated weeds, thus preventing the weeds to attain full growth (Pandey *et al.*, 2003).

b) Effect of weed management

It was evident from the data (Table 4.26) that weed management treatments had significant effect on dicot weed population density at 30, 60 and 90 DAS in both the years as well as in pooled data. Analysed pooled data indicated that two hand weeding treatment at 20 and 40 DAS recorded significantly lower dicot weed population density at 30, 60 and 90 DAS as 7.22, 8.19 and 5.57 m^{-2} respectively which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS at 30, 60 and 90 DAS as 9.51, 10.45and 7.65 m^{-2} respectively. Weedy check had the highest dicot weed population density at all the growth stages in both the years as well as pooled data. All the weed management treatments significantly reduced the dicot weed population density than that of the weedy check. Similar result was also reported by Patel *et al*. (2016).

c) Interaction effect on dicot weed population

The interaction effect of planting geometry and weed management treatments on dicot weed population at 60 and 90 DAS was found to have significant effect in both the years as well as the pooled data. Maize + soybean (2:2) planting geometry with two hand weeding at 20 and 40 DAS recorded significantly lower dicot weed population density at 60 and 90 DAS as 6.83 and 4.60 m^{-2} respectively which was at par with two hand weeding at 20 and 40 DAS in maize + black gram (2:2) planting geometry as 8.08 and 5.27 m^{-2} respectively.

4.4.2 Weed fresh weight studies

I. Monocot weed fresh weight

The data of monocot weed fresh weight as influenced by planting geometry and weed management at 30 days interval was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and their pooled data calculated. The data were presented in Table 4.28 & 4.29 and graphically depicted as Fig 4.29 & 4.30.

a) Effect of planting geometry

Analysis of data showed that planting geometry failed to bring significant effect on fresh biomass weight of monocot weed at 30 DAS in both the years as well as in pooled data.

At 60 and 90 DAS, different planting geometry patterns proved significant reduction in fresh biomass weight of monocot weed in both the years and pooled data. The fresh weight of monocot weed was reduced significantly in maize + soybean (2:2) as compared to maize + black gram (1:1).The lowest monocot weed fresh weight was recorded from maize + soybean (2:2) at 60 and 90 DAS as 311.95 and 283.42 g m^{-2} respectively followed by maize + black gram (2:2) at 60 and 90 DAS as 330.34 and 294.97 g m^{-2} respectively. Maize + soybean (2:2) were more effective in controlling monocot weeds in the present studies.

b) Effect of weed management

Weed management treatments recorded significantly lower monocot weed fresh weight as compared to weedy check at 30, 60 and 90 DAS in both the years and pooled data. The pooled data showed the lowest monocot weed fresh weight in two hand weeding at 20 and 40 DAS as 82.85, 106.96 and 92.61 g m^{-2} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 108.34, 169.17 and 124.81 g m^{-2} at 30, 60 and 90 DAS respectively. The highest monocot weed fresh weight was recorded with weedy check as 518.05, 764.32 and 697.21 g m^{-2} at 30, 60 and 90 DAS respectively.

c) Interaction effect on monocot weed fresh weight

The interaction effect of planting geometry and weed management treatments on monocot weed fresh weight at 60 and 90 DAS was found to have significant effect in both the years as well as in pooled data. The lowest monocot weed fresh weight as 86.90 and 77.58 g m^{-2} was recorded in maize + soybean (2:2) with two hand weeding at 20 and 40 DAS at 60 and 90 DAS respectively followed by maize + black gram (2:2) with hand weeding at 20 and 40 DAS as 90.1 and 85.53 g m^{-2} at 60 and 90 DAS respectively. The maximum monocot weed fresh weight as 799.46 and 710.37 g m^{-2} were recorded in maize + black gram (1:1) with weedy check at 60 and 90 DAS.

II. Dicot weed fresh weight

The data regarding dicot weed fresh weight as influenced by planting geometry and weed management at 30 days interval was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and data were presented in Table 4.30 & 4.31 and graphically depicted as Fig 4.31 & 4.32.

a) Effects of planting geometry

A perusal of data (Table 4.30) showed that planting geometry patterns failed to bring significant effect in fresh biomass weight of dicot weed at 30 DAS in both the years and pooled data.

The maximum reduction in dicot weed fresh weight as 56.69 and 25.21 g m^{-2} were recorded with maize + soybean (2:2) followed by maize + black gram (2:2) as 59.35 and 27.04 g m^{-2} at 60 and 90 DAS respectively.

b) Effect of weed management

All the weed management treatments significantly influenced the fresh weight of dicot weed at all stages of crop growth *i.e.* 30, 60 and 90 DAS in both the years and pooled data. Pooled data revealed that weedy check produced the maximum fresh weight of dicot weed as 74.20, 129.01 and 44.70 g m^{-2} at 30, 60 and 90 DAS, respectively. Two hand weeding at 20 and 40 DAS recorded the minimum fresh weight of dicot weed as 21.44, 25.22 and 16.50 g m^{-2} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 28.80, 30.95 and 22.81 g m^{-2} at 30, 60 and 90 DAS respectively.

c) Interaction effect on dicot weed fresh weight

The interaction effect of planting geometry and weed management treatments on dicot weed fresh weight at 60 and 90 DAS was found to have significant effect in both the years as well as in pooled data. The pooled data showed that minimum dicot weed fresh weight was recorded in maize + soybean (2:2) with two hand weedings at 20 and 40 DAS as 18.83 and 13.63 g m^{-2} which was statistically at par with maize + black gram (2:2) as 21.70 and 15.63 g m^{-2} at 60 and 90 DAS respectively.

4.4.3 Weed dry weight studies

I. Monocot weed dry weight

The data of monocot weed dry weight as influenced by planting geometry and weed management at 30 days interval was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and presented along with their pooled data as Table 4.32 & 4.33 and graphically depicted as Fig 4.33 & 4.34.

a) Effect of planting geometry

The data showed that planting geometry did not have significant effect on dry matter accumulation of monocot weed at 30 DAS in both the years and pooled data.

The effect of planting geometry on dry matter accumulation by monocot weed was found to be statistically significant at 60 and 90 DAS. The minimum dry matter production by monocot weed was recorded with maize + soybean (2:2) at 60 and 90 DAS as 31.57 and 28.17 g m^{-2} respectively which was statistically at par with maize + black gram (2:2) as 32.82 and 29.38 g m^{-2} at 60 and 90 DAS respectively. Weed dry matter accumulation in intercropping system might be attributed to shading effect and competition stress created by the canopy of more number of crops in an unit area having suppressive effect on associated weeds, thus preventing the weed to attain full growth (Pandey *et al.,* 2003). Bhuvaneshwari *et al*. (2002) also reported reduction in weed dry matter by intercropping maize with cowpea and soybean in Tamil Nadu.

b) Effect of weed management

All the weed management treatments significantly reduced the dry matter production of monocot weed over weedy check at 30, 60 and 90 DAS in both the years and pooled data. Among the weed management treatments, two hand weeding at 20 and 40 DAS produced minimum monocot weed dry weight as 8.10, 10.93 and 10.10 g m^{-2} followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW 30 DAS as 10.63, 17.02 and 12.65 g m^{-2} at 30, 60 and 90 DAS respectively. Chalka and Nepalia (2006) reported that hand weeding significantly reduced dry matter accumulation by monocot weed as compared to weedy check.

c) Interaction effect on monocot weed dry weight

The interaction effects of planting geometry and weed management treatments on monocot weed dry weight at 60 and 90 DAS were found to have significant effect in both the years as well as in pooled data. The pooled data showed that maize + soybean (2:2) with two hand weeding at 20 and 40 DAS produced the lowest monocot weed dry matter as 8.95 and 7.98 g m^{-2} at 60 and 90 DAS respectively. The highest monocot weed dry matter weight was recorded from the interaction of maize + black gram (1:1) and weedy check as 8.76 and 8.36 g m^{-2} at 60 and 90 DAS respectively.

II. Dicot weed dry weight

The data of dicot weed dry weight as influenced by planting geometry and weed management at 30 days interval was recorded at 30, 60 and 90 DAS in both the years during *kharif*, 2016 and 2017 and their pooled data calculated. The data were presented in Table 4.34 & 4.35 and graphically depicted as Fig 4.35 & 4.36.

a) Effect of planting geometry

Different planting geometry did not significantly influence the dry matter accumulation of dicot weed at 30 DAS in both the years and pooled data.

At 60 and 90 DAS, the dry matter accumulation of dicot weed was significantly influenced by different planting geometry in both the years. The pooled data showed that the dry matter of dicot weed were significantly reduced in maize + soybean (2:2) as 5.85 g m^2 and 2.68 g m^{-2} which was statistically at par with maize + black gram (2:2) as 6.14 and 2.90 g m^{-2} at 60 and 90 DAS respectively. Maize + black gram (1:1) gave the highest weed dry matter weight as 6.74 and 3.23 g m^{-2} at 60 and 90 DAS respectively.

Kithan and Longkumer (2014) reported the lowest dry weed weight with maize + soybean (2:2). This might be due to lesser weed population and better smothering effect in that particular denser row arrangement of crops limiting the growth of weeds. The present findings were in conformity with that of Mohandoss *et al*. (2002).

b) Effect of weed management

The effect of weed management treatments on dry matter accumulation of dicot weed was found to be statistically significant at 30, 60 and 90 DAS in both the years and pooled data. Two hand weeding at 20 and 40 DAS produced the minimum dicot weed dry matter followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW 30 DAS at 30, 60 and 90 DAS in both the years and pooled data. Pooled data revealed that weedy check produced the maximum dry matter of dicot weed as 7.30, 12.81 and 4.59 g m^{-2} at 30, 60 and 90 DAS, respectively.

Chalka and Nepalia (2006) reported reduction in dicot weed dry matter by adopting different weed control measures as compared to weedy check.

c) Interaction effects on dicot weed dry weight

The interaction effects of planting geometry and weed management treatments on dicot weed dry weight at 60 and 90 DAS were found to have significant effect in both the years as well as pooled data. The pooled data showed that maize + soybean (2:2) with two hand weeding at 20 and 40 DAS produced the minimum dicot weed dry weight as 2.27 and 1.47 g m^{-2} at 60 and 90 DAS respectively.

4.4.4 Summary pooled mean of total weed population m^{-2}, fresh weight and dry weight g m^{-2} as effected by planting geometry and weed control treatment in maize based intercropping with black gram and soybean

The summary pooled mean of total weed population m^{-2}, fresh weight and dry weight g m^{-2} as influenced by planting geometry and weed management practices in maize based intercropping with black gram and soybean (Table 4.36) revealed that among the planting geometry studied, 2M:2SB planting geometry was found to be the best method of planting in respect of weed management for total weed population, fresh weight and dry weight.

Among the weed management treatments, two hand weeding at 20 and 40 DAS was found to be the best weed management practice in respect of total weed population, fresh weight and dry weight.

Among the combination treatments, 2M:2SB planting geometry combined with two hand weeding at 20 and 40 DAS was found to be the best treatment combination in the present studies on maize based intercropping with black gram and soybean as effected by planting geometry and weed control treatments in respect of total weed population, fresh weight and dry weight.

4.5 Competitive Indices as enfluenced by planting geometry and weed management in maize based intercropping with black gram and soybean

Various parameters of competitive indices in maize based intercropping with black gram and soybean as influenced by planting geometry and weed management practices were presented and discussed hereunder.

4.5.1 Land Equivalent Ratio (LER)

The data on LER as affected by planting geometry, weed management and combination treatments in maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

As per the pooled data, the highest LER was recorded from maize + soybean (2:2) as 1.47 which meant that there was 47% yield advantage of intercropping over sole cropping followed by maize + soybean (1:1) as 1.40 *i.e.* 40% yield advantage of intercropping over sole cropping. Patra *et al*. (1990) was of the opinion that LER might increased through better utilization of soil moisture, light and nutrients by component crops in intercropping systems. Higher LER value under maize + soybean intercropping was also recorded by Haque *et al*. (2016).

b) Effect of weed management

The pooled data revealed that all the weed management treatments increased LER over weedy check. Weed management treatment with two hand weeding at 20 and 40 DAS recorded the highest LER as 1.60 *i.e.* 60% yield advantage of intercropping over sole cropping followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.56 *i.e.* 56% yield advantage of intercropping over sole cropping. Weedy check recorded lower value of LER as 1.04 *i.e.* 4% yield advantage of intercropping over sole cropping.

c) Interaction effect on LER

A perusal on the data pertaining to LER, it was observed that the highest LER was recorded as 1.70 with the treatment maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS followed by maize + soybean (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.66.

4.5.2 Area Time Equivalent Ratio (ATER)

The data on ATER as affected by planting geometry, weed management and combination treatments in maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

The higher value of ATER of planting geometry was recorded with maize + soybean (2:2) as 1.25 *i.e.* there is yield advantage of intercropping and it was closely followed by maize + black gram (2:2) as 1.23. Maize + soybean (2:2) planting geometry recorded the highest ATER value which might be due to the development of temporal as well as spatial complementarity. Mohan *et al*. (2005) also reported the higher value of ATER in maize + legume in 1:2 proportion than 1:1 proportion.

b) Effect of weed management

The pooled data showed that weed management treatment of two hand weeding at 20 and 40 DAS obtained the highest ATER value as 1.37 which was followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1}

+ one HW at 30 DAS as 1.33. The lower ATER of 0.91 was recorded in weedy check.

c) Interaction effect on ATER

A perusal on the data pertaining to ATER, it was observed that the highest ATER was recorded as 1.43 with the treatment maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS followed by maize + soybean (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.39.

4.5.3 Relative crowding coefficient (RCC)

The data on RCC as affected by planting geometry, weed management and combination treatments of maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

Pooled data showed that among planting geometry, maize + soybean (2:2) recorded the highest RCC value of 122.03. The lowest RCC was recorded with maize + black gram (1:1) as 7.20. As the value of RCC was more than 1, there was yield advantage in the intercropping.

b) Effect of weed management

As per pooled data, the weed management treatment of two hand weeding at 20 and 40 DAS recorded the highest RCC as 97.68 followed by pre-emergence application of pendimethalin @ 1.0 a.i.ha^{-1} + one HW at 30 DAS as 31.25. The lowest RCC was recorded in weedy check as 1.16. As the value of RCC was more than 1, even the weedy check had the yield advantage in the present intercropping system.

c) Interaction effect on RCC

A perusal on the data pertaining to RCC, it was observed that the highest RCC was recorded as 295.94 with the treatment maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS followed by maize + soybean (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 68.85.

4.5.4 Aggressivity (A)

The data on aggresivity as affected by planting geometry, weed management and combination treatments in maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

In the aggressivity studies of different planting geometry, maize was found to be the dominant crop (+ve) while the associated black gram and soybean appeared as dominated crops (-ve). The highest aggressivity value of 0.21 with maize + black gram (1:1) followed by maize + soybean (1:1) as 0.18, maize + black gram (2:2) as 0.13 and maize + soybean (2:2) as 0.11 were obtained as the effect of planting geometry. Maize + black gram (1:1) planting geometry resulted the higher value of aggressivity which indicated a higher interspecific competition as compared to maize +soybean (2:2). Similar result was reported by Kheroar and Patra (2013). Patra *et al*. (1990) also reported the dominant effect of maize when grown in association with legumes.

b) Effect of weed Management

Pooled data showed that among the weed management treatments, weedy check recorded the minimum value of aggressivity (0.06) thereby indicated the dominance of component crops which could be minimized by suitable planting geometry and weed management and thus cropping system might be made more remunerative.

c) Interaction effect on aggressivity

A perusal on the data pertaining to aggressivity, it was observed that the highest aggressivity value of maize was found as 0.27 with the treatment maize + black gram (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Similar aggressivity value of 0.27 was also observed with maize + black gram (1:1) combined with two hand weeding at 20 and 40 DAS.

4.5.5 Competitive ratio (CR)

The data on Competitive ratio (CR) as affected by planting geometry, weed management and combination treatments in maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

Among the planting geometry, higher competitive ratio of maize was recorded with maize + black gram (2:2) as 1.44 whereas maize + soybean (1:1) was recorded less competitive ratio of 1.28. So, maize (being a C_4 plant) appeared to be more competitive and subsidiary legume intercrops were found to be less competitive with respect to utilization of available resources. Patra *et al*. (1990) reported that maize was found to be more competitive and legumes to be less in all intercropping system.

b) Effect of weed management

Pooled data of competitive ratio indicated that among weed management treatments, pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS recorded a higher value of competitive ratio as

1.45 which was closely followed by hand weeding at 20 and 40 DAS as 1.44. The lowest competitive ratio was recorded under weedy check as 1.18.

c) Interaction effect on competitive ratio

A perusal on the data pertaining to competitive ratio, it was observed that the highest competitive ratio of maize was recorded as 1.58 with the treatment maize + black gram (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS followed by maize + black gram (2:2) combined with two hand weeding at 20 and 40 DAS as 1.57. The highest competitive ratio of maize with legume intercrop was recorded as 0.86 with the treatment maize + black gram (1:1) combined with weedy check.

4.5.6 Relative value Total (RVT)

The data on Relative value total (RVT) as affected by planting geometry and weed management and combination treatments in maize intercropped with black gram and soybean were presented in Table 4.37 & 4.37(a).

a) Effect of planting geometry

Pooled data of the highest value of RVT was obtained from planting geometry with maize + soybean (2:2) as 1.44 which was closely followed by the planting geometry with maize + soybean (1:1) as 1.37. The lowest RVT was obtained from maize + black gram (1:1) as 1.20. Maize + soybean (2:2) planting geometry brought about a higher RVT value probably due to higher combined yield of maize + legume association. The present result was in agreement with the finding of Patra *et al*. (1999). Mandal *et al*. (2014) reported that RVT of maize + soybean was found to be superior over that of maize + groundnut.

b) Effect of weed management

Weed management treatments with two hand weedings at 20 and 40 DAS indicated the highest RVT value of 1.52 which was followed by pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS with RVT value of 1.47. The lowest RVT value of 0.97 was observed in weedy check.

c) Interaction effect on RVT

A perusal on the data pertaining to RVT, it was observed that the highest RVT was recorded as 1.67 with the treatment maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS followed by maize + soybean (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.62.

4.6 Economics (₹ ha^{-1}) of maize based intercropping with black gram and soybean as influenced by planting geometry and weed management

4.6.1 Net Return (₹ ha^{-1})

The data pertaining to net return under different planting geometry, weed management practices and combination treatments were presented in Table 4.38 & 4.38(a).

a) Effect of planting geometry

On pooled basis, the maximum net return of ₹ 34802.52 ha^{-1} were obtained from the planting geometry with paired row planting of maize + soybean (2:2). The result was in close conformity with the findings of Shivay *et al.* (2001), Padhi and Panigrahi (2006) and Kaushal *et al*. (2015). Similar finding was also reported by Kithan and Longkumer (2014 and 2016) and Panwar *et al*. (2016).

b) Effect of weed management

The pooled data showed that among the weed management treatments the highest net return was recorded from pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as ₹ 36624.05 ha^{-1}, which was closely followed by two hand weeding at 20 and 40 DAS as ₹ 35428.81 ha^{-1}. Similar finding was also reported by Shah *et al*. (2011). Pandey *et al*. (2001) concluded that the chemical control of weeds was more economical than hand weeding. The minimum net return was recorded in weedy check as ₹ 18636.54 ha^{-1}. Similar finding was also reported by Shah *et al*. (2011).

c) Interaction effect on net return (₹ ha^{-1})

Data pertaining to net return (₹ ha^{-1}) as a result of combination treatment of planting geometry and weed management practices revealed that the highest net return (₹ ha^{-1}) was obtained from the treatment maize + soybean (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as ₹ 42319.22 which was closely followed by maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS as ₹ 41239.54. The lowest net return (₹ ha^{-1}) was recorded as ₹ 16453.48 from maize + black gram (1:1) combined with weedy check. The highest net return (₹ ha^{-1}) in the treatment maize + soybean (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS might be due to less expenditure involved through the use of chemical weedicide for the treatment.

4.6.2 Return per rupee investment

The data pertaining to return per rupee investment under different treatments *viz.* planting geometry, weed management practices and combination treatments were presented in Table 4.38 & 4.38(a).

a) Effect of planting geometry

The pooled data showed that planting geometry of maize + soybean (2:2) recorded the highest return per rupee investment as 2.31 when compared to other planting geometry patterns. The lowest return per rupee investment was observed with maize + black gram (1:1) as 2.01 per rupee investment.

b) Effect of weed management

Among the weed management treatments, the highest return per rupee investment was obtained as 2.43 in pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS followed by two hand weeding at 20 and 40 DAS as 2.24. The minimum return per rupee investment was estimated from weedy check as 1.83.

c) Interaction effect on return per rupee invested

A perusal on the data pertaining to return per rupee invested, it was observed that the highest return per rupee invested was recorded as 2.61 with the treatment maize + soybean (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS followed by the treatment maize + soybean (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 2.47. The lowest return per rupee invested was recorded as 1.75 with the treatment maize + black gram (1:1) combined with weedy check. The higher return per rupee invested might be due to less expenditure involved by the use of chemical weedicide instead of costly manual labours in hand weeding.

4.6.3 B:C ratio

Data related to benefit: cost ratio of maize with intercrops as influenced by different treatments were summarised in Table 4.38 and their interactions in Table 4.38(a).

a) Effect of planting geometry

The highest B: C ratio of 1.31 was observed under maize + soybean (2:2) followed by maize + soybean (1:1) as 1.20. The lowest B:C ratio was recorded in maize + black gram (1:1) as 1.01. The reason for the highest B:C ratio in maize + soybean (2:2) planting geometry may be due to the highest net return. Similar finding was reported by Panwar *et al*. (2016) and Kithan and Longkumer (2014).

b) Effect of weed management

The pooled data revealed that among the weed management treatments the highest B:C ratio was recorded with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.43 followed by two hand weeding at 20 and 40 DAS as 1.24. The lowest B:C ratio was recorded in weedy check as 0.83.

c) Interaction effect on B:C ratio

On examination of data on B:C ratio in respect of interaction effect of planting geometry and weed management practices, it was observed that the highest B:C ratio of 1.61 was recorded from the treatment maize + soybean (2:2) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS and the lowest B:C ratio of 0.75 was recorded from the treatment combination maize + black gram (1:1) combined with weedy check. The higher B:C ratio in the present studies reflected the economical superiority of maize + soybean intercropping in 2:2 combination with the use of pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS than the other treatment combinations.

4.7 Soil health (chemical and microbial) in the maize based intercropping with black gram and soybean as influenced by planting geometry and weed management practices

4.7.1 Soil chemical properties

1. Soil pH

The data pertaining to soil pH after crop harvest for two years of experimentations during *kharif*, 2016 and 2017 as influenced by planting geometry and weed management practices were presented in Table 4.39.

a) Effect of planting geometry

Different planting geometry did not show any significant effect on soil pH in both the years and pooled data.

b) Effect of weed management

Soil pH was not significantly influenced by weed management practices in both the years and pooled data. The pooled data showed the lowest soil pH of 4.51 in weedy check.

c) Interaction on effect on soil pH

The interaction effect of planting geometry and weed management practices did not show any significant effect on soil pH in both the years as well as the pooled data.

2. Soil organic carbon (%)

The data on available organic carbon (%) in soil at harvest for two years of experimentations as influenced by planting geometry and weed management practices were presented in Table 4.39.

a) Effect of planting geometry

Available soil organic carbon was not significantly influenced by different planting geometry in both the years and pooled data.

b) Effect of weed management

Available soil organic carbon was not significantly influenced by the weed management practices in both the years and pooled data.

c) Interaction effect on soil organic carbon (%)

The interaction effect of planting geometry and weed management practices did not show any significant effect on soil organic carbon in both the years as well as pooled data.

3. Available Soil N, P and K after harvest

The data on available soil nitrogen, phosphorus and potassium at harvest for two years of experimentations *i.e. kharif*, 2016 and 2017 as influenced by planting geometry and weed management practices were presented in Table 4.39 & 4.39(a).

I. Soil Available Nitrogen

a) Effect of planting geometry

The result showed that available soil nitrogen was not significantly influenced by different planting geometry in both the years and pooled data.

b) Effect of weed management

Available soil nitrogen was not significantly influenced by different weed management treatments in both the years and pooled data.

c) Interaction effect on available N

The interaction effect of planting geometry and weed management treatments did not show statistically significant effect on available soil N in both the years as well as pooled data. However, it was observed that maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS and maize + black gram (2:2) combined with two hand weeding at 20 and 40 DAS gave numerically the highest available soil nitrogen to the tune of 241.20 kg ha^{-1} and 239.97 kg ha^{-1} respectively as against the lowest available soil nitrogen content of 219.63 kg ha^{-1} recorded with maize + black gram (1:1) combined with weedy check. Hence, it was clear from the present studies that intercropping of maize with soybean with two hand weeding at 20 and 40 DAS certainly influence in increasing available soil nitrogen content.

II. Soil Available Phosphorus (P)

a) Effect of planting geometry

The result showed that available soil phosphorus was not influenced by different planting geometry in both the years and pooled data.

b) Effect of weed management

The result showed that available soil phosphorus was not influenced by the weed management treatments in both the years and pooled data.

c) Interaction effect on available P

The interaction effect of planting geometry and weed management treatments did not show statistically significant effect on available P in both the years as well as pooled data. It was further revealed that maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS gave 20.42 kg ha^{-1} of available soil phosphorous against 18.50 kg ha^{-1} in maize + black gram (1:1) combined with weedy check. It was, therefore, inferred that there was certainly some added advantage in increasing soil available phosphorus by planting geometry *i.e.* maize + soybean (2:2) combined with weed management practices *i.e.* two hand weeding at 20 and 40 DAS.

III. Soil Available Potasssium (K)

a) Effect of planting geometry

The result showed that available soil potassium was not significantly influenced by different planting geometry in both the years and pooled data.

b) Effect of weed management

The result showed that available soil potassium was not significantly influenced by the weed management practices in both the years and pooled data.

c) Interaction effect on available K

The interaction effect of planting geometry and weed management treatments did not show statistically significant effect on available soil K in both the years as well as pooled data. Further perusal on the data revealed that maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS gave numerically the highest available soil potassium as 207.5 kg ha^{-1} in the present studies. The lowest value of available soil potassium was recorded from the maize + black gram (1:1) combined with weedy check as 195.12 kg ha^{-1}. It indicated that maize + soybean (2:2) planting geometry combined with two hand weeding at 20 and 40 DAS was advantageous in the availability of soil potassium in maize based intercropping with soybean.

4.7.2 Soil microbial population

The data regarding soil microbial population count such as bacteria, PSB, fungi and actinomycetes as influenced by planting geometry and weed management practices at 30 days interval were recorded at 30, 60 and 90 DAS in both the years *i.e. kharif*, 2016 and 2017.

I. Soil Bacteria

The data on soil microbial population of bacteria in maize based intercropping with black gram and soybean were presented in Table 4.40 & 4.40(a).

a) Effect of planting geometry

At 30, 60 and 90 DAS, planting geometry patterns did not show significant effect on bacterial population in both the years and pooled data.

b) Effect of weed management

During the two years of experimentation *i.e. kharif*, 2016 and 2017 and their pooled results indicated that the effect of weed management treatments on soil bacterial population was not statistically significant at 30, 60 and 90 DAS.

c) Interaction effect on bacterial population

The interaction effect of planting geometry and weed management treatments did not show statistically significant effect on bacterial population in both the years as well as pooled data. It was further observed that soil bacterial population increased from 30 DAS and reached the highest at 60 DAS, thereafter the population declined towards 90 DAS in the present studies.

Numerically the highest soil bacterial population of 16.28 was recorded from maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS and the lowest soil bacterial population of 13.68 was recorded with maize + black gram (1:1) with weedy check at 60 DAS in the present studies.

II. Phosphate solubilising bacteria (PSB)

The data of soil microbial population of PSB in maize based intercropping with black gram and soybean were presented in Table 4.41 & 4.41(a).

a) Effect of planting geometry

At 30, 60 and 90 DAS, different planting geometry patterns did not show any significant effect on PSB population in both the years and pooled data.

b) Effect of weed management

At 30, 60 and 90 DAS, weed management treatments were not significantly increased the PSB population in both the years and pooled data.

c) Interaction effect on PSB population

The interaction effect of planting geometry and weed management treatments did not show any significant effect on PSB population in both the years as well as pooled data. However, numerically the highest soil PSB population of 16.53 was recorded from maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS and the lowest was recorded as 14.57 with maize + black gram (1:1) combined with weedy check at 60 DAS in the present studies.

III. Soil Fungi

The data of soil microbial population of soil fungi in maize based intercropping with black gram and soybean were presented in Table 4.42 & 4.42(a).

a) Effect of planting geometry

At 30, 60 and 90 DAS, different planting geometry did not show any significant effect on fungi population in both the years and pooled data.

b) Effect of weed management

During the two years of experimentation *i.e. kharif*, 2016 and 2017 and their pooled results indicated that the effect of weed management treatments on fungi population were not statistically significant at 30, 60 and 90 DAS.

c) Interaction effect on soil fungi population

The interaction effect of planting geometry and weed management treatments did not show statistically significant effect on fungi population in both the years as well as pooled data. The highest soil fungi population was recorded as 7.60 with maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS and the lowest soil fungi population was recorded as 6.32 with maize + black gram (1:1) combined with weedy check at 60 DAS.

IV. Soil Actinomycetes

The data of soil microbial population of soil actinomycetes in maize based intercropping with black gram and soybean were presented in Table 4.43 & 4.43(a).

a) Effect of planting geometry

At 30, 60 and 90 DAS, different planting geometry did not show any significant effect on actinomycetes population in both the years and pooled data.

b) Effect of weed management

In both the years of experimentation and their pooled data indicated that the effect of weed management treatments on actinomycetes population was statistically not significant at 30, 60 and 90 DAS.

c) Interaction effect on actinomycetes population

The interaction effect of planting geometry and weed management practices did not show any significant effect on soil actinomycetes population in both the years as well as pooled data. However, numerically the highest soil actinomycetes population was recorded as 15.38 at 90 DAS under maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS and the lowest population was recorded from maize + black gram (1:1) with weedy check as 13.05 at 90 DAS.

SUMMARY AND CONCLUSION

An investigation entitled **"Evaluation of Maize (*Zea mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition"** was carried out in the Experimental Farm of ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during the two consecutive *kharif* seasons of 2016 and 2017 with the following objectives:

i. To study the effect of planting geometry and weed management practices in maize + legume intercropping systems.
ii. To study the effect of maize + legume intercropping systems on soil health.
iii. To study the economics of maize + legume intercropping systems.

The experiment was laid out in Randomized Block Design with two factors (planting geometry and weed management) comprising twelve treatment combinations and replicated three times. The relevant field experimental results were presented and discussed in the preceding chapters and their summary and conclusion were given as under:

5.1 Summary

5.1.1 Effect of planting geometry on maize based intercropping with black gram and soybean

a) Plant growth and phenological parameters

i. Maize

- Different planting geometry (1M:1BG, 2M:2BG, 1M:SB and 2M:2SB) did not have statistically significant effect on plant growth parameters of maize *viz*. plant height, number of leaves plant^{-1}, leaf area index and stem diameter at 30 DAS in both the years and pooled data. However, statistically significant influenced of planting geometry on plant height and leaf area index were observed at 60 and 90 DAS in both the years and pooled data. On the contrary, the number of leaves plant^{-1} and stem diameter were not significantly influenced by the planting geometry at 60 and 90 DAS in both the years and pooled data.

- Different planting geometry failed to produce any significant effect on phenological parameters *viz*., days to 50% tasseling and 50% silking in both the years and pooled data.

ii. Black gram and soybean

- All the plant growth parameters of black gram and soybean *viz*. plant height, number of branches plant^{-1}, number of leaves plant^{-1}, leaf area index and number of nodules plant^{-1} under different planting geometry did not have any significant effect on all plant growth stages in both the years and pooled data.

b) Yield attributes and crop yield

i. Maize

- The yield attributing characters of maize *viz*. number of cobs plant^{-1}, number of grain row cob^{-1} and 1000 grain weight (g) did not effect significantly by different planting geometry in both the years and pooled data. However, number of grains row^{-1} was found to be significantly influenced by the planting geometry.
- Grain yield and stover yield of maize were significantly influenced by the planting geometry studied. The highest pooled grain yield and stover yield of maize were recorded as 2565.96 kg ha^{-1} and 5043.59 kg ha^{-1}

from maize + soybean (2:2) followed by maize + black gram (2:2) as 2505.12 kg ha^{-1} and 4946.68 kg ha^{-1} respectively.

- Maize equivalent yield was significantly different among planting geometry studied. Maize + soybean (2:2) recorded the highest maize equivalent yield as 4374.96 kg ha^{-1} which was statistically at par with maize + soybean (1:1) as 4165.55 kg ha^{-1} in both the years and pooled data.

ii. Black gram and soybean

- The yield attributing characters of black gram and soybean *viz*. number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight (g) as well as the seed and stover yield of black gram and soybean under different planting geometry did not show statistically significant effect in both the years and pooled data.

5.1.2 Effect of weed management on maize based intercropping with black gram and soybean

a) Plant growth and phenological parameters

i. Maize

- The weed management practices had significant effect on plant growth parameters of maize *viz*. plant height, number of leaves plant^{-1}, leaf area index and stem diameter at 30, 60 and 90 DAS in both the years and pooled data. However, weed management practices failed to produce any significant effect on phenological parameters *viz*., days to 50% tasseling and 50% silking in both the years and pooled data.

ii. Black gram and soybean

- The weed management practices had significant effect on increasing plant growth parameters of black gram and soybean *viz*. plant height, number of branch plant^{-1}, number of leaves plant^{-1}, leaf area index and number nodules plant^{-1} at 30, 60 DAS and at harvest for black gram and 30, 60 and 90 DAS for soybean in both the years and pooled data.

b) Yield attributes and crop yield

i. Maize

- The weed management practices effect significantly in yield attributing characters of maize *viz*. number of cobs plant^{-1}, number of grain rows cob^{-1} and number of grains row^{-1} in both the years and pooled data. However, weed management practices did not effect significantly in 1000 grain weight (g) of maize.
- The weed management practices had significant effect on grain yield and stover yield of maize in both the years and pooled data. The highest grain yield and stover yield of maize were recorded by two hand weeding at 20 and 40 DAS (2851.33 kg ha^{-1}) which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS (2779.83 kg ha^{-1}).
- The weed management practices had significant effect on maize equivalent yield in both the years and pooled data. The highest maize equivalent yield was recorded by two hand weeding at 20 and 40 DAS as 4591.10 kg ha^{-1} which was statistically at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 4461.80 kg ha^{-1}.

ii. Black gram and soybean

- The weed management practices had significant effect on increasing yield attributing characters of black gram and soybean *viz*. number of pods plant^{-1} and number of seeds pod^{-1} in both the years and pooled data. However, weed management practices did not have significant effect on 1000 seed weight (g) of black gram and soybean.

- Seed yield and stover yield were significantly increased in black gram and soybean by weed management practices. Two hand weeding at 20 and 40 DAS recorded the highest seed yield and stover yield of black gram as 389.22 and 805.38 kg ha^{-1}, respectively and soybean as 969.53 and 2064.87 kg ha^{-1}, respectively in the present studies.

5.1.3 Interaction effect of planting geometry and weed management on maize based intercropping with black gram and soybean

- Interaction effects of combination treatments of planting geometry and weed management practices did not show any significant effect on plant growth parameters and yield attributes of maize in both the years and pooled data. However, interaction effects of combination treatments of planting geometry and weed management practices had significant effect on grain yield of maize (3000.67 kg ha^{-1}), stover yield of maize (5793.98 kg ha^{-1}) and maize equivalent yield (5055.30 kg ha^{-1}) in two years pooled data. On the contrary, interaction effects of combination treatments of planting geometry and weed management practices did not have significant effect on plant growth parameters, yield attributes and seed yield and stover yield of black gram and soybean in both the years and pooled data.
- Statistically significant increase in grain yield of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS followed by maize + soybean (2:2) with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS in the present studies might be due to the cumulative effects of better plant growth and higher values of yield attributes, although statistically, not significant, resulted from better

arrangement of row spacing, adequate weed control and better utilization of natural resources.

- From the present studies on interaction effects of planting geometry and weed management practices, it was observed that plant growth and development parameters and yield attributes of main crop (maize) and component crops (black gram and soybean) behaved or acted independently within the acceptable limits of statistical significance. However, there was small observable numerical differences in the performance of combination treatments.

5.2 Weed studies as effected by planting geometry and weed management

5.2.1 Effect of planting geometry

- Different planting geometry did not have significant effect on weed population, fresh weight and dry weight of monocot and dicot weeds at 30 DAS in both years and pooled data. However, at 60 and 90 DAS, different planting geometry significantly influenced in reducing weed population, fresh weight and dry weight of monocot and dicot weeds in both years and pooled data.
- Planting geometry maize + soybean (2:2) reduced significantly the weed population, fresh weight and dry weight of monocot and dicot weeds which were statistically at par with maize + black gram (2:2) at 60 and 90 DAS in both years and pooled data.

5.2.2 Effect of weed management practices

- All the weed management practices were significantly effective over weedy check at 30, 60 and 90 DAS. Two hand weeding at 20 and 40 DAS recorded the lowest weed population, fresh weight and dry weight of monocot and dicot weeds which was at par with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS.

5.2.3 Interaction effect of planting geometry and weed management on maize based intercropping with black gram and soybean

- Interaction effect of planting geometry and weed management practices did not have significant effect on weed population, fresh weight and dry weight of monocot and dicot weeds at 30 DAS in both years and pooled data. However, interaction effect of planting geometry and weed management practices had significant effect on weed population, fresh weight and dry weight of monocot and dicot weeds at 60 and 90 DAS in both years and pooled data.
- Among the combination treatments, maize + soybean (2:2) planting geometry combined with two hand weeding at 20 and 40 DAS was found to be the best in reducing weed population, fresh weight and dry weight of monocot and dicot weeds in the present studies.

5.3 Competitive Indices of maize based intercropping with black gram and soybean as influenced by planting geometry and weed management

5.3.1 Effect of planting geometry

- The highest LER, ATER, RCC and RVT were obtained from maize + soybean (2:2) as 1.47, 1.25, 122.03 and 1.44 respectively *i.e.* yield advantage of intercropping over sole cropping in the present studies.
- The highest aggressivity (A) value of maize as 0.21 was obtainrd with maize + black gram (1:1) which was closely followed by maize + soybean (1:1) as 0.18, maize + black gram (2:2) as 0.13 and maize + soybean (2:2) as 0.11. Among the planting geometry, maize was found to be the dominant crop (+ve) while the associated black gram and soybean appeared as dominated crops (-ve).
- Among the planting geometry, higher competitive ratio (CR) of maize was recorded with maize + black gram (2:2) as 1.44 whereas, maize +

black gram (1:1), maize + soybean (1:1) and maize + soybean (2:2) were recorded less competitive ratio of 1.36, 1.28 and 1.34 respectively. So, maize (being a C_4 plant) appeared to be more competitive and the subsidiary intercrops were found to be less competitive with respect to utilization of available resources.

5.3.2 Effect of weed management practices

- Weed management practices with two hand weeding at 20 and 40 DAS recorded the highest LER (1.60), ATER (1.37), RCC (97.68) and RVT (1.52) which indicated the yield advantage of intercropping over sole cropping.
- Among the weed management practices, the highest competitive ratio (CR) and aggressivity (A) value were recorded from pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.45 and 0.21 respectively followed by two hand weeding at 20 and 40 DAS 1.44 and 0.20 respectively.

5.3.3 Interaction effect on competitive indices of planting geometry and weed management

- The maximum LER, ATER, RCC and RVT were obtained from the treatment combination maize + soybean (2:2) with two hand weeding at 20 and 40 DAS as 1.7, 1.43, 295.94 and 1.67 respectively.
- The highest aggressivity (A) value of 0.27 was recorded from the treatment maize + black gram (1:1) combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. Similar aggressivity value of 0.27 was also obtained with maize + black gram (1:1) combined with two hand weeding at 20 and 40 DAS.
- The highest competitive ratio (CR) of maize was obtained from the treatment combination of maize + black gram (2:2) with pre-emergence

application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 1.58.

5.4 Economics (₹ ha^{-1}) of maize based intercropping with black gram and soybean as influenced by planting geometry and weed management (estimated from maize equivalent yield)

5.4.1 Effect of planting geometry

- The maximum net return, return per rupee investment and B:C ratio as ₹ 34802.52 ha^{-1}, 2.31 and 1.31 respectively were obtained from the planting geometry with paired row planting of maize + soybean (2:2) followed by maize + soybean (1:1) as ₹ 31882.21 ha^{-1} 2.20 and 1.20 respectively.

5.4.2 Effect of weed management practices

- Among the weed management practices, the highest net return, return per rupee investment and B:C ratio were obtained from pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS with ₹ 36624.05 ha^{-1}, 2.43 and 1.43 followed by two hand weeding at 20 and 40 DAS with ₹ 35428.81 ha^{-1}, 2.24 and 1.24 respectively.

5.4.3 Interaction effect on economics of planting geometry and weed management

- As a result of interaction effect of planting geometry and weed management practices in maize based intercropping with black gram and soybean, the highest net return (₹ ha^{-1}), return per rupee investment and B:C ratio were obtained from the treatment combination maize + soybean (2:2) with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as ₹ 42319.22 ha^{-1}, 2.61 and 1.61 respectively against the lowest net return (₹ ha^{-1}), return per investment and B:C ratio as ₹ 16453.48 ha^{-1}, 1.75 and 0.75 from the treatment combination maize + black gram (1:1) with weedy check.

5.5 Soil health in maize based intercropping with black gram and soybean as influenced by planting geometry and weed management practices

5.5.1 Effect of planting geometry

- Different planting geometry pattern did not show any significant effect on soil pH and soil organic carbon. Similarly, available Soil N, P and K after harvest were also not significantly influenced by different planting geometry in both the years and pooled data.
- Soil microbial population count *viz*. bacteria, PSB, fungi and actinomycetes were not significantly influenced by different planting geometry in both the years and pooled data.
- Among the soil microbes, microbial population increased from 30 DAS to a maximum of 60 DAS and thereafter the population declined towards 90 DAS in soil bacteria, PSB and soil fungi. However, in the case of soil actinomycetes, the population increased from 30 DAS till 90 DAS.

5.5.2 Effect of weed management practices

- The effect of weed management practices did not show any significant effect on soil pH and soil organic carbon. Similarly, available soil N, P and K after harvest were also not significantly influenced by weed management treatments in both the years and pooled data.
- Soil microbial population count *viz*. bacteria, PSB, fungi and actinomycetes were not significantly influenced by weed management treatments in both the years and pooled data.

5.5.3 Interaction effect of planting geometry and weed management on soil health

- Soil pH was not affected significantly by the interaction effect of planting geometry and weed management practices in maize based intercropping with black gram and soybean.
- The highest soil organic carbon of 0.40% was recorded from the combination treatment of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS and the lowest being in the maize + black gram (1:1) with weedy check as 0.33% but the difference was not statistically significant.
- The highest available soil N, P, and K were recorded from the combination treatment of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS as 241.20 kg ha^{-1}, 20.40 kg ha^{-1} and 207.5 kg ha^{-1} respectively and the lowest available soil N, P and K were recorded from the combination treatment of maize + black gram (1:1) with weedy check as 219.63 kg ha^{-1}, 18.50 kg ha^{-1} and 195.12 kg ha^{-1} respectively but the difference was not statistically significant. The present studies, however, inffered that intercropping of maize with soybean certainly influence in increasing available soil nitrogen during the crop growth.
- In respect of soil microbial population, the combination treatment of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS gave the highest microbial population in respect of soil bacteria, PSB, soil fungi and actinomycetes as 16.28, 16.53, 7.60 and 15.38 C.F.U. respectively while the lowest population was recorded as 13.68, 14.57, 6.32 and 13.05 respectively from the combination treatment of maize + black gram (1:1) with weedy check. Although the difference was not statistically significant, there was a clear numerical difference between the highest and lowest soil microbial population in combination treatments.

Conclusion

- On the basis of the results of two years of experimentations during *kharif* 2016 and 2017 on maize based intercropping with black gram and soybean as influenced by planting geometry and weed management practices, it was concluded as under:
- Planting geometry (1M:1BG, 2M:2BG, 1M:1SB ANS 2M:2SB) had statistically significant influence only on 6 parameters of maize *viz.*, plant height, leaf area index, number of grains row^{-1}, grain yield, stover yield and maize equivalent yield, out of the total 13 plant growth and yield parameters studied. On the contrary, different planting geometry did not have statistically significant influence on all the plant growth and yield parameters of black gram and soybean.
- A total of 10 parameters of maize *viz.*, plant height, number of leaves, leaf area index, stem diameter, number of cobs plant^{-1}, number of grains row cob^{-1}, number of grains row^{-1}, grain yield, stover yield and maize equivalent yield were significantly influenced by the weed management practices (W_0, W_1 and W_2). Similarly, weed management practices had statistically significant influence on all the plant growth and yield parameters of black gram and soybean except 1000 grain weight.
- Interaction effects of combination treatments of planting geometry and weed management practices in maize based intercropping with black gram and soybean revealed statistically significant effect only on maize grain yield, stover yield of maize and maize equivalent yield while there were no statistically significant effect of combination treatments on plant growth parameters, yield attributes, seed yield and stover yield of component crops *i.e.* black gram and soybean.
- In the present intercropping studies, the highest grain yield of maize was obtained as 3,000.67 kg ha^{-1} from maize + soybean (2:2) with two hand weeding at 20 and 40 DAS which was statistically at par with maize +

black gram (2:2) with two hand weeding at 20 and 40 DAS as 2936.95 kg ha^{-1} and maize + soybean (2:2) with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS as 2932.17 kg ha^{-1}. In terms of maize equivalent yield, the highest yield was obtained as 5055.30 kg ha^{-1} from maize + soybean (2:2) with two hand weeding at 20 and 40 DAS.

- In respect of weed studies, maize + soybean (2:2) planting geometry combined with two hand weeding at 20 and 40 DAS was found to be the best in the present studies in reducing weed population, fresh weight and dry weight of monocot and dicot weeds.
- The maximum competitive indices of LER, ATER, RCC, and RVT as 1.7, 1.43, 295.94 and 1.67 respectively were obtained from the treatment combination of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS. The highest aggressivity (A) value of 0.27 was estimated from maize + black gram (1:1) planting geometry combined either with two hand weeding at 20 DAS and 40 DAS or with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS. In respect of competitive ratio (CR) of maize, the highest value of 1.58 was obtained from maize + black gram (2:2) with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS.
- In the present studies, the highest net return, return per rupee invested and B:C ratio, estimated from maize equivalent yield, as ₹ 42,319.22 ha^{-1}, 2.61 and 1.61 respectively were obtained from maize + soybean (2:2) with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS.
- Soil health parameters *viz.*, soil pH, soil organic carbon, available soil N, P, K and soil microbial population were not influenced significantly by the planting geometry, weed management practices and their

combination treatments in the present studies. However it was observed that the combination treatment of maize + soybean (2:2) with two hand weeding at 20 and 40 DAS gave the highest numerical advantage in all soil health parameters studied.

Recommendation

Based on two years field experimental data on the **evaluation of maize (*Zea mays* L.) based intercropping systems as influenced by planting geometry and weed management practices under rainfed condition**. The following recommendations are hereby suggested:

1. For maize based intercropping with black gram or soybean, maize + soybean (2:2) planting geometry may be recommended under the rainfed conditions of Nagaland for maximum maize equivalent yield and stover yield.
2. Either two hand weeding at 20 and 40 DAS or pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS may be recommended in maize based intercropping with soybean under rainfed conditions of Nagaland for better weed control and maximum yield.
3. Among the combination treatments in maize based intercropping with soybean and black gram under different planting geometry and weed management practices, maize + soybean (2:2) combined with two hand weeding at 20 and 40 DAS was found to be the best treatment combination in respect of agronomic indices *viz*., LER, ATER, RCC and RVT and soil health parameters *viz*., soil organic carbon, available soil N, P and K and soil microbial populations in the present studies.
4. For environment friendly crop productivity maize + soybean (2:2) planting geometry combined with two hand weeding at 20 and 40 DAS

may be recommended for obtaining maximum grain and stover yield of maize and soybean in maize based intercropping with soybean.

5. For economic profitability, maize + soybean (2:2) planting geometry combined with pre-emergence application of pendimethalin @ 1.0 kg a.i.ha^{-1} + one HW at 30 DAS may be recommended to obtain maximum net return (₹ ha^{-1}), return per rupee invested and B:C ratio in maize based intercropping with soybean.

Suggestions for further studies

As experienced from the present studies on cereal (maize) + legume (black gram and soybean) intercropping for productivity and profitability through various crop production parameters, agronomic indices, soil health parameters and economic indices, the following suggestions are hereby made for further research on cereal + legume intercropping systems.

1. Finding out better crop compatibility for space, sunshine, nutrient, moisture etc. in cereal + legume intercropping amongst the *kharif* and *rabi* cereals and legumes with varied crop management practices for better productivity, profitability and sustainability as compared to sole cropping either in hill or valley has now become a necessity for sustainable agriculture in N.E.H Region.
2. Cereal + legume intercropping provided a greater scope for minimizing the adverse impact of nutrient stress in addition to soil health improvement. Hence, it is important to assess appropriate nutrient doses and management practices for cereal component in the intercropping systems considering the sparring effect of biological nitrogen fixation (BNF) from leguminous component for maximum productivity and profitability.
3. Intercropping offers a potential solution to control weed pressure by reducing niche space available for weeds; however, available research

on the relationship between crop diversity and weed pressure and it consequences on crop yield is not yet fully conclusive. Hence, intercropping experiments using a number of cereal + legume crop combinations to examine as to how crop diversity affects weed communities and how subsequent changes in weeds influence in crop yield has become indeed a necessity in the weed management strategies of cereal + legume intercropping system.

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APPENDICES

Pooled anova table of maize based intercropping system as influenced by planting geometry and weed management

ANOVA I (a): Pooled analysis of variance on maize plant height (cm) at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	61.32	15.33	0.33	2.58	NS
Factor A	6	96.18	16.03	0.34	2.31	NS
Factor B	4	980.10	245.02	5.26	2.58	S
A x B interaction	12	0.93	0.08	0.00	1.98	NS
Error	44	2048.23	46.55			

ANOVA I (b): Pooled analysis of variance on maize plant height (cm) at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	116.38	29.10	1.45	2.58	NS
Factor A	6	279.94	46.66	2.33	2.31	S
Factor B	4	7509.75	1877.44	93.76	2.58	S
A x B interaction	12	81.33	6.78	0.34	1.98	NS
Error	44	881.02	20.02			

ANOVA I (c): Pooled analysis of variance on maize plant height (cm) at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	203.03	50.76	1.86	2.58	NS
Factor A	6	823.52	137.25	5.04	2.31	S
Factor B	4	11831.97	2957.99	108.52	2.58	S
A x B interaction	12	40.75	3.40	0.12	1.98	NS
Error	44	1199.28	27.26			

ANOVA I (d): Pooled analysis of variance on number of maize leaves plant^{-1} at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.50	0.13	0.18	2.58	NS
Factor A	6	1.01	0.17	0.24	2.31	NS
Factor B	4	15.05	3.76	5.44	2.58	S
A x B interaction	12	0.07	0.01	0.01	1.98	NS
Error	44	30.43	0.69			

ANOVA I (e): Pooled analysis of variance on number of maize leaves plant^{-1} at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.53	0.38	0.21	2.58	NS
Factor A	6	0.80	0.13	0.07	2.31	NS
Factor B	4	46.18	11.54	6.27	2.58	S
A x B interaction	12	0.03	0.00	0.00	1.98	NS
Error	44	81.06	1.84			

ANOVA I (f): Pooled analysis of variance on number of maize leaves plant^{-1} at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.33	0.33	0.15	2.58	NS
Factor A	6	0.81	0.14	0.06	2.31	NS
Factor B	4	56.55	14.14	6.26	2.58	S
A x B interaction	12	0.06	0.01	0.00	1.98	NS
Error	44	99.39	2.26			

ANOVA I (g): Pooled analysis of variance on stem diameter size (cm) of maize plant at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.02	0.00	0.20	2.58	NS
Factor A	6	0.02	0.00	0.14	2.31	NS
Factor B	4	0.59	0.15	6.21	2.58	S
A x B interaction	12	0.00	0.00	0.01	1.98	NS
Error	44	1.05	0.02			

ANOVA I (h): Pooled analysis of variance on stem diameter size (cm) of maize plant at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.12	2.58	NS
Factor A	6	0.03	0.00	0.16	2.31	NS
Factor B	4	0.77	0.19	6.53	2.58	S
A x B interaction	12	0.00	0.00	0.00	1.98	NS
Error	44	1.29	0.03			

ANOVA I (i): Pooled analysis of variance on stem diameter size (cm) of maize plant at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.03	0.01	0.28	2.58	NS
Factor A	6	0.02	0.00	0.11	2.31	NS
Factor B	4	0.75	0.19	6.14	2.58	S
A x B interaction	12	0.00	0.00	0.00	1.98	NS
Error	44	1.35	0.03			

ANOVA I (j): Pooled analysis of variance on leaf area index of maize plant at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.05	2.58	NS
Factor A	6	0.04	0.01	0.31	2.31	NS
Factor B	4	0.49	0.12	5.16	2.58	S
A x B interaction	12	0.00	0.00	0.01	1.98	NS
Error	44	1.05	0.02			

ANOVA I (k): Pooled analysis of variance on leaf area index of maize plant at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.04	0.01	1.32	2.58	NS
Factor A	6	0.27	0.05	5.99	2.31	S
Factor B	4	15.49	3.87	512.44	2.58	S
A x B interaction	12	0.01	0.00	0.13	1.98	NS
Error	44	0.33	0.01			

ANOVA I (l): Pooled analysis of variance on leaf area index of maize plant at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.03	0.01	0.91	2.58	NS
Factor A	6	0.33	0.05	6.20	2.31	S
Factor B	4	17.46	4.36	497.06	2.58	S
A x B interaction	12	0.01	0.00	0.13	1.98	NS
Error	44	0.39	0.01			

ANOVA I (m): Pooled analysis of variance on maize days to 50% tasseling in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	6.70	1.67	0.64	2.58	NS
Factor A	6	3.28	0.55	0.21	2.31	NS
Factor B	4	21.97	5.49	2.10	2.58	NS
A x B interaction	12	0.32	0.03	0.01	1.98	NS
Error	44	114.85	2.61			

ANOVA I (n): Pooled analysis of variance on maize days to 50% silking in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.06	0.76	0.16	2.58	NS
Factor A	6	1.48	0.25	0.05	2.31	NS
Factor B	4	49.31	12.33	2.55	2.58	NS
A x B interaction	12	0.12	0.01	0.00	1.98	NS
Error	44	212.57	4.83			

ANOVA I (o): Pooled analysis of variance on number of maize cobs plant^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.05	0.01	0.87	2.58	NS
Factor A	6	0.13	0.02	1.62	2.31	NS
Factor B	4	1.29	0.32	23.98	2.58	S
A x B interaction	12	0.08	0.01	0.47	1.98	NS
Error	44	0.59	0.01			

ANOVA I (p): Pooled analysis of variance on number of maize grain rows cob^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.52	0.13	0.06	2.58	NS
Factor A	6	2.98	0.50	0.24	2.31	NS
Factor B	4	42.38	10.59	5.19	2.58	S
A x B interaction	12	0.26	0.02	0.01	1.98	NS
Error	44	89.74	2.04			

ANOVA I (q): Pooled analysis of variance on number of maize grains row^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	2.02	0.51	1.02	2.58	NS
Factor A	6	12.12	2.02	4.07	2.31	S
Factor B	4	156.21	39.05	78.76	2.58	S
A x B interaction	12	1.78	0.15	0.30	1.98	NS
Error	44	21.82	0.50			

ANOVA I (r): Pooled analysis of variance on maize 1000 grain wt. (g) in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	206.14	51.53	1.47	2.58	NS
Factor A	6	11.02	1.84	0.05	2.31	NS
Factor B	4	81.39	20.35	0.58	2.58	NS
A x B interaction	12	2.52	0.21	0.01	1.98	NS
Error	44	1542.72	35.06			

ANOVA I (s): Pooled analysis of variance on maize grain yield kg ha^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	23193.59	5798.40	1.46	2.58	NS
Factor A	6	723855.87	120642.65	30.42	2.31	S
Factor B	4	20015494.59	5003873.65	1261.77	2.58	S
A x B interaction	12	125185.88	10432.16	2.63	1.98	S
Error	44	174493.20	3965.75			

ANOVA I (t): Pooled analysis of variance on maize stover yield kg ha^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	72269.73	18067.43	1.31	2.58	NS
Factor A	6	2430156.47	405026.08	29.28	2.31	S
Factor B	4	58386523.73	14596630.93	1055.30	2.58	S
A x B interaction	12	432055.41	36004.62	2.60	1.98	S
Error	44	608595.55	13831.72			

ANOVA I (u): Pooled analysis of variance on maize equivalent yield kg ha^{-1} in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	22677.86	5669.47	1.24	2.58	NS
Factor A	6	6121394.79	1020232.47	222.92	2.31	S
Factor B	4	40150892.40	10037723.10	2193.25	2.58	S
A x B interaction	12	615353.73	51279.48	11.20	1.98	S
Error	44	201372.49	4576.65			

ANOVA II (a): Pooled analysis of variance on black gram plant height (cm) at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	7.36	1.84	0.20	2.87	NS
Factor A	2	5.04	2.52	0.28	3.49	NS
Factor B	4	156.70	39.18	4.28	2.87	S
A x B interaction	4	0.32	0.08	0.01	2.87	NS
Error	20	183.24	9.16			

ANOVA II (b): Pooled analysis of variance on black gram plant height (cm) at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	21.65	5.41	0.22	2.87	NS
Factor A	2	12.49	6.24	0.25	3.49	NS
Factor B	4	411.80	102.95	4.13	2.87	S
A x B interaction	4	0.24	0.06	0.00	2.87	NS
Error	20	499.06	24.95			

ANOVA II (c): Pooled analysis of variance on black gram plant height (cm) at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	22.00	5.50	0.16	2.87	NS
Factor A	2	15.47	7.74	0.23	3.49	NS
Factor B	4	569.05	142.26	4.20	2.87	S
A x B interaction	4	0.29	0.07	0.00	2.87	NS
Error	20	677.50	33.88			

ANOVA II (d): Pooled analysis of variance on number of leaves plant^{-1} of black gram at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.69	0.42	0.13	2.87	NS
Factor A	2	1.32	0.66	0.20	3.49	NS
Factor B	4	55.63	13.91	4.18	2.87	S
A x B interaction	4	0.12	0.03	0.01	2.87	NS
Error	20	66.60	3.33			

ANOVA II (e): Pooled analysis of variance on number of leaves plant^{-1} of black gram at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	7.65	1.91	0.17	2.87	NS
Factor A	2	3.64	1.82	0.16	3.49	NS
Factor B	4	189.73	47.43	4.28	2.87	S
A x B interaction	4	0.12	0.03	0.00	2.87	NS
Error	20	221.60	11.08			

ANOVA II (f): Pooled analysis of variance on number of leaves plant^{-1} of black gram at harvest in maize based intercropping system as influenced by planting geometry and weed management.

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	4.63	1.16	0.16	2.87	NS
Factor A	2	2.92	1.46	0.20	3.49	NS
Factor B	4	123.00	30.75	4.17	2.87	S
A x B interaction	4	0.01	0.00	0.00	2.87	NS
Error	20	147.32	7.37			

ANOVA II (g): Pooled analysis of variance on number of branch $plant^{-1}$ of black gram at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.19	0.05	0.19	2.87	NS
Factor A	2	0.04	0.02	0.08	3.49	NS
Factor B	4	4.16	1.04	4.29	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	4.85	0.24			

ANOVA II (h): Pooled analysis of variance on number of branch $plant^{-1}$ of black gram at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.21	0.05	0.19	2.87	NS
Factor A	2	0.04	0.02	0.07	3.49	NS
Factor B	4	4.68	1.17	4.21	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	5.55	0.28			

ANOVA II (i): Pooled analysis of variance on number of branch $plant^{-1}$ of black gram at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.30	0.08	0.24	2.87	NS
Factor A	2	0.16	0.08	0.25	3.49	NS
Factor B	4	5.46	1.37	4.27	2.87	S
A x B interaction	4	0.01	0.00	0.01	2.87	NS
Error	20	6.39	0.32			

ANOVA II (j): Pooled analysis of variance on leaf area index of black gram at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.19	2.87	NS
Factor A	2	0.00	0.00	0.23	3.49	NS
Factor B	4	0.07	0.02	4.25	2.87	S
A x B interaction	4	0.00	0.00	0.02	2.87	NS
Error	20	0.08	0.00			

ANOVA II (k): Pooled analysis of variance on leaf area index of black gram at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.11	2.87	NS
Factor A	2	0.01	0.00	0.13	3.49	NS
Factor B	4	0.58	0.14	4.35	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	0.66	0.03			

ANOVA II (l): Pooled analysis of variance on leaf area index of black gram at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.04	0.01	0.10	2.87	NS
Factor A	2	0.03	0.02	0.18	3.49	NS
Factor B	4	1.67	0.42	4.20	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	1.98	0.10			

ANOVA II (m): Pooled analysis of variance on number of nodules plant^{-1} of black gram at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	2.89	0.72	0.15	2.87	NS
Factor A	2	2.56	1.28	0.27	3.49	NS
Factor B	4	77.96	19.49	4.18	2.87	S
A x B interaction	4	0.21	0.05	0.01	2.87	NS
Error	20	93.19	4.66			

ANOVA II (n): Pooled analysis of variance on number of nodules plant^{-1} of black gram at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.37	0.34	0.03	2.87	NS
Factor A	2	6.26	3.13	0.30	3.49	NS
Factor B	4	173.86	43.47	4.15	2.87	S
A x B interaction	4	0.33	0.08	0.01	2.87	NS
Error	20	209.43	10.47			

ANOVA II (o): Pooled analysis of variance on number of pods plant^{-1} of black gram in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	9.00	2.25	0.10	2.87	NS
Factor A	2	7.48	3.74	0.17	3.49	NS
Factor B	4	416.36	104.09	4.68	2.87	S
A x B interaction	4	0.29	0.07	0.00	2.87	NS
Error	20	445.11	22.26			

ANOVA II (p): Pooled analysis of variance on number of seeds pod^{-1} of black gram in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.34	0.08	0.22	2.87	NS
Factor A	2	0.14	0.07	0.18	3.49	NS
Factor B	4	6.59	1.65	4.33	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	7.61	0.38			

ANOVA II (q): Pooled analysis of variance on 1000 seed wt. of black gram in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.60	0.90	0.11	2.87	NS
Factor A	2	1.98	0.99	0.12	3.49	NS
Factor B	4	94.82	23.70	2.84	2.87	NS
A x B interaction	4	0.15	0.04	0.00	2.87	NS
Error	20	166.74	8.34			

ANOVA II (r): Pooled analysis of variance on seed yield kg ha^{-1} of black gram in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	735.44	183.86	1.00	2.87	NS
Factor A	2	405.74	202.87	1.10	3.49	NS
Factor B	4	55489.71	13872.43	75.37	2.87	S
A x B interaction	4	19.52	4.88	0.03	2.87	NS
Error	20	3681.30	184.06			

ANOVA II (s): Pooled analysis of variance on stover yield kg ha^{-1} of black gram in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	2162.38	540.60	2.03	2.87	NS
Factor A	2	1182.03	591.01	2.22	3.49	NS
Factor B	4	157861.25	39465.31	148.07	2.87	S
A x B interaction	4	78.50	19.63	0.07	2.87	NS
Error	20	5330.56	266.53			

ANOVA III (a): Pooled analysis of variance on soybean plant height (cm) at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	5.52	1.38	0.12	2.87	NS
Factor A	2	4.63	2.31	0.20	3.49	NS
Factor B	4	195.49	48.87	4.18	2.87	S
A x B interaction	4	0.07	0.02	0.00	2.87	NS
Error	20	233.98	11.70			

ANOVA III (b): Pooled analysis of variance on soybean plant height (cm) at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	26.46	6.61	0.22	2.87	NS
Factor A	2	14.26	7.13	0.23	3.49	NS
Factor B	4	507.27	126.82	4.15	2.87	S
A x B interaction	4	0.47	0.12	0.00	2.87	NS
Error	20	611.90	30.60			

ANOVA III (c): Pooled analysis of variance on soybean plant height (cm) at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	58.08	14.52	0.24	2.87	NS
Factor A	2	27.99	14.00	0.23	3.49	NS
Factor B	4	1008.59	252.15	4.19	2.87	S
A x B interaction	4	1.60	0.40	0.01	2.87	NS
Error	20	1202.58	60.13			

ANOVA III (d): Pooled analysis of variance on number of leaves plant^{-1} of soybean at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.96	0.24	0.12	2.87	NS
Factor A	2	0.87	0.44	0.22	3.49	NS
Factor B	4	33.34	8.33	4.14	2.87	S
A x B interaction	4	0.02	0.01	0.00	2.87	NS
Error	20	40.26	2.01			

ANOVA III (e): Pooled analysis of variance on number of leaves plant^{-1} of soybean at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	5.41	1.35	0.14	2.87	NS
Factor A	2	3.76	1.88	0.19	3.49	NS
Factor B	4	172.37	43.09	4.30	2.87	S
A x B interaction	4	0.15	0.04	0.00	2.87	NS
Error	20	200.43	10.02			

ANOVA III (f): Pooled analysis of variance on number of leaves plant^{-1} of soybean at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	9.84	2.46	0.21	2.87	NS
Factor A	2	6.09	3.04	0.26	3.49	NS
Factor B	4	192.22	48.06	4.15	2.87	S
A x B interaction	4	0.76	0.19	0.02	2.87	NS
Error	20	231.79	11.59			

ANOVA III (g): Pooled analysis of variance on number of branch plant^{-1} of soybean at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.05	0.01	0.10	2.87	NS
Factor A	2	0.04	0.02	0.16	3.49	NS
Factor B	4	2.12	0.53	4.12	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	2.56	0.13			

ANOVA III (h): Pooled analysis of variance on number of branch plant^{-1} of soybean at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.50	0.12	0.15	2.87	NS
Factor A	2	0.07	0.04	0.04	3.49	NS
Factor B	4	15.70	3.92	4.87	2.87	S
A x B interaction	4	0.01	0.00	0.00	2.87	NS
Error	20	16.12	0.81			

ANOVA III (i): Pooled analysis of variance on number of branch plant^{-1} of soybean at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.41	0.10	0.14	2.87	NS
Factor A	2	0.07	0.04	0.05	3.49	NS
Factor B	4	12.14	3.04	4.30	2.87	S
A x B interaction	4	0.01	0.00	0.00	2.87	NS
Error	20	14.12	0.71			

ANOVA III (j): Pooled analysis of variance on leaf area index of soybean at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.14	2.87	NS
Factor A	2	0.00	0.00	0.08	3.49	NS
Factor B	4	0.39	0.10	4.83	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	0.40	0.02			

ANOVA III (k): Pooled analysis of variance on leaf area index of soybean at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.03	0.01	0.25	2.87	NS
Factor A	2	0.01	0.00	0.17	3.49	NS
Factor B	4	0.53	0.13	4.57	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	0.58	0.03			

ANOVA III (l): Pooled analysis of variance on leaf area index of soybean at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.07	2.87	NS
Factor A	2	0.01	0.00	0.12	3.49	NS
Factor B	4	0.58	0.15	4.12	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	0.70	0.04			

ANOVA III (m): Pooled analysis of variance on number of nodules plant^{-1} of soybean at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.54	0.13	0.12	2.87	NS
Factor A	2	0.28	0.14	0.13	3.49	NS
Factor B	4	19.11	4.78	4.25	2.87	S
A x B interaction	4	0.06	0.02	0.01	2.87	NS
Error	20	22.50	1.13			

ANOVA III (n): Pooled analysis of variance on number of nodules plant^{-1} of soybean at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	17.04	4.26	0.11	2.87	NS
Factor A	2	6.60	3.30	0.08	3.49	NS
Factor B	4	769.61	192.40	4.94	2.87	S
A x B interaction	4	0.81	0.20	0.01	2.87	NS
Error	20	778.62	38.93			

ANOVA III (o): Pooled analysis of variance on number of pods plant^{-1} of soybean in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	71.18	17.80	0.23	2.87	NS
Factor A	2	31.04	15.52	0.20	3.49	NS
Factor B	4	1381.78	345.45	4.47	2.87	S
A x B interaction	4	0.72	0.18	0.00	2.87	NS
Error	20	1545.83	77.29			

ANOVA III (p): Pooled analysis of variance on number of seeds pod^{-1} of soybean in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.06	0.01	0.11	2.87	NS
Factor A	2	0.04	0.02	0.15	3.49	NS
Factor B	4	2.42	0.60	4.41	2.87	S
A x B interaction	4	0.00	0.00	0.00	2.87	NS
Error	20	2.74	0.14			

ANOVA III (q): Pooled analysis of variance on 1000 seed wt. of soybean in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	15.16	3.79	0.22	2.87	NS
Factor A	2	6.46	3.23	0.18	3.49	NS
Factor B	4	197.82	49.46	2.82	2.87	NS
A x B interaction	4	1.27	0.32	0.02	2.87	NS
Error	20	351.15	17.56			

ANOVA III (r): Pooled analysis of variance on seed yield kg ha^{-1} of soybean in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	5167.61	1291.90	2.53	2.87	NS
Factor A	2	3420.22	1710.11	3.35	3.49	NS
Factor B	4	708727.91	177181.98	346.96	2.87	S
A x B interaction	4	390.34	97.58	0.19	2.87	NS
Error	20	10213.32	510.67			

ANOVA III (s): Pooled analysis of variance on stover yield kg ha^{-1} of soybean in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	22663.25	5665.81	2.48	2.87	NS
Factor A	2	14807.56	7403.78	3.24	3.49	NS
Factor B	4	2306862.46	576715.61	252.74	2.87	S
A x B interaction	4	1883.60	470.90	0.21	2.87	NS
Error	20	45636.48	2281.82			

Pooled anova table of weed population studies in maize based intercropping system as influenced by planting geometry and weed management

ANOVA IV (a): Pooled analysis of variance on no. of monocot weeds m^{-2} at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.51	0.13	0.67	2.58	NS
Factor A	6	2.47	0.41	2.19	2.31	NS
Factor B	4	755.30	188.83	1000.87	2.58	S
A x B interaction	12	0.35	0.03	0.15	1.98	NS
Error	44	8.30	0.19			

ANOVA IV (b): Pooled analysis of variance on no. of monocot weeds m^{-2} at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.56	0.14	0.64	2.58	NS
Factor A	6	16.04	2.67	12.37	2.31	S
Factor B	4	1292.02	323.00	1494.64	2.58	S
A x B interaction	12	6.81	0.57	2.63	1.98	S
Error	44	9.51	0.22			

ANOVA IV (c): Pooled analysis of variance on no. of monocot weeds m^{-2} at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.28	0.07	0.49	2.58	NS
Factor A	6	13.47	2.25	15.58	2.31	S
Factor B	4	1206.58	301.65	2092.84	2.58	S
A x B interaction	12	4.44	0.37	2.57	1.98	S
Error	44	6.34	0.14			

ANOVA IV (d): Pooled analysis of variance on no. of dicot weeds m^{-2} at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.30	0.08	0.75	2.58	NS
Factor A	6	0.88	0.15	1.48	2.31	NS
Factor B	4	53.94	13.48	135.32	2.58	S
A x B interaction	12	0.24	0.02	0.20	1.98	NS
Error	44	4.38	0.10			

ANOVA IV (e): Pooled analysis of variance on no. of dicot weeds m^{2} at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.06	2.58	NS
Factor A	6	1.79	0.30	11.99	2.31	S
Factor B	4	167.18	41.79	1677.89	2.58	S
A x B interaction	12	0.82	0.07	2.73	1.98	S
Error	44	1.10	0.02			

ANOVA IV (f): Pooled analysis of variance on no. of dicot weeds m^{-2} at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.48	2.58	NS
Factor A	6	0.94	0.16	27.87	2.31	S
Factor B	4	24.53	6.13	1091.31	2.58	S
A x B interaction	12	0.18	0.01	2.62	1.98	S
Error	44	0.25	0.01			

ANOVA IV (g): Pooled analysis of variance on fresh wt. (g m^{-2}) of monocot weeds at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	4.88	1.22	1.32	2.58	NS
Factor A	6	12.75	2.12	2.30	2.31	NS
Factor B	4	2718.92	679.73	735.09	2.58	S
A x B interaction	12	5.84	0.49	0.53	1.98	NS
Error	44	40.69	0.92			

ANOVA IV (h): Pooled analysis of variance on fresh wt. (g m^{-2}) of monocot weeds at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	5.27	1.32	2.46	2.58	NS
Factor A	6	71.02	11.84	22.10	2.31	S
Factor B	4	4200.85	1050.21	1960.87	2.58	S
A x B interaction	12	22.93	1.91	3.57	1.98	S
Error	44	23.57	0.54			

ANOVA IV (i): Pooled analysis of variance on fresh wt. (g m^{-2}) of monocot weeds at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	2.96	0.74	1.70	2.58	NS
Factor A	6	34.12	5.69	13.08	2.31	S
Factor B	4	4146.50	1036.63	2384.44	2.58	S
A x B interaction	12	14.60	1.22	2.80	1.98	S
Error	44	19.13	0.43			

ANOVA IV (j): Pooled analysis of variance on fresh wt. (g m^{-2}) of dicot weeds at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	4.54	1.13	0.48	2.58	NS
Factor A	6	8.79	1.46	0.62	2.31	NS
Factor B	4	225.86	56.47	24.00	2.58	S
A x B interaction	12	2.35	0.20	0.08	1.98	NS
Error	44	103.51	2.35			

ANOVA IV (k): Pooled analysis of variance on fresh wt. (g m^{-2}) of dicot weeds at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.05	0.01	0.16	2.58	NS
Factor A	6	7.87	1.31	17.71	2.31	S
Factor B	4	592.01	148.00	1997.62	2.58	S
A x B interaction	12	2.30	0.19	2.59	1.98	S
Error	44	3.26	0.07			

ANOVA IV (l): Pooled analysis of variance on fresh wt. (g m^{-2}) of dicot weeds at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.06	0.01	0.93	2.58	NS
Factor A	6	3.29	0.55	34.35	2.31	S
Factor B	4	87.92	21.98	1376.17	2.58	S
A x B interaction	12	0.55	0.05	2.85	1.98	S
Error	44	0.70	0.02			

ANOVA IV (m): Pooled analysis of variance on dry wt. (g m^{-2}) of monocot weeds at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.29	0.07	0.70	2.58	NS
Factor A	6	0.73	0.12	1.17	2.31	NS
Factor B	4	235.71	58.93	568.37	2.58	S
A x B interaction	12	0.11	0.01	0.09	1.98	NS
Error	44	4.56	0.10			

ANOVA IV (n): Pooled analysis of variance on dry wt. (g m^{-2}) of monocot weeds at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.20	0.05	0.67	2.58	NS
Factor A	6	5.00	0.83	11.40	2.31	S
Factor B	4	396.33	99.08	1356.26	2.58	S
A x B interaction	12	2.34	0.20	2.67	1.98	S
Error	44	3.21	0.07			

ANOVA IV (o): Pooled analysis of variance on dry wt. (g m^{-2}) of monocot weeds at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.20	0.05	0.99	2.58	NS
Factor A	6	3.99	0.66	13.25	2.31	S
Factor B	4	383.75	95.94	1912.66	2.58	S
A x B interaction	12	1.67	0.14	2.78	1.98	S
Error	44	2.21	0.05			

ANOVA IV (p): Pooled analysis of variance on dry wt. (g m^{-2}) of dicot weeds at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.02	0.01	0.17	2.58	NS
Factor A	6	0.30	0.05	1.61	2.31	NS
Factor B	4	15.83	3.96	125.90	2.58	S
A x B interaction	12	0.07	0.01	0.19	1.98	NS
Error	44	1.38	0.03			

ANOVA IV (q): Pooled analysis of variance on dry wt. (g m^{-2}) of dicot weeds at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.12	2.58	NS
Factor A	6	0.52	0.09	10.68	2.31	S
Factor B	4	50.36	12.59	1557.98	2.58	S
A x B interaction	12	0.26	0.02	2.66	1.98	S
Error	44	0.36	0.01			

ANOVA IV (r): Pooled analysis of variance on dry wt. (g m^{-2}) of dicot weeds at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.41	2.58	NS
Factor A	6	0.25	0.04	21.01	2.31	S
Factor B	4	6.89	1.72	858.27	2.58	S
A x B interaction	12	0.07	0.01	2.97	1.98	S
Error	44	0.09	0.00			

Pooled anova table of soil chemical properties in maize based intercropping system as influenced by planting geometry and weed management.

ANOVA V (a): Pooled analysis of variance on soil pH at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.01	0.00	0.25	2.58	NS
Factor A	6	0.01	0.00	0.21	2.31	NS
Factor B	4	0.05	0.01	2.37	2.58	NS
A x B interaction	12	0.00	0.00	0.01	1.98	NS
Error	44	0.24	0.01			

ANOVA V (b): Pooled analysis of variance on soil OC% at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.00	0.00	0.20	2.58	NS
Factor A	6	0.01	0.00	0.40	2.31	NS
Factor B	4	0.02	0.01	2.38	2.58	NS
A x B interaction	12	0.00	0.00	0.03	1.98	NS
Error	44	0.09	0.00			

ANOVA V (c): Pooled analysis of variance on soil N at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	285.23	71.31	0.19	2.58	NS
Factor A	6	270.53	45.09	0.12	2.31	NS
Factor B	4	3816.59	954.15	2.55	2.58	NS
A x B interaction	12	29.74	2.48	0.01	1.98	NS
Error	44	16480.75	374.56			

ANOVA V (d): Pooled analysis of variance on soil P at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.96	0.99	0.41	2.58	NS
Factor A	6	3.15	0.52	0.22	2.31	NS
Factor B	4	24.19	6.05	2.51	2.58	NS
A x B interaction	12	0.39	0.03	0.01	1.98	NS
Error	44	105.98	2.41			

ANOVA V (e): Pooled analysis of variance on soil K at harvest in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Year	1	242.73	242.73	1.82	4.06	NS
Replication	4	250.74	62.68	0.47	2.58	NS
Factor A	6	96.13	16.02	0.12	2.31	NS
Factor B	4	1361.13	340.28	2.56	2.58	NS
A x B interaction	12	9.43	0.79	0.01	1.98	NS
Error	44	5852.61	133.01			

Pooled anova table of soil microbial population of bacteria in maize based intercropping system as influenced by planting geometry and weed management

ANOVA VI (a): Pooled analysis of variance on soil microbial population of bacteria at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	5.71	1.43	0.18	2.58	NS
Factor A	6	3.61	0.60	0.08	2.31	NS
Factor B	4	81.84	20.46	2.57	2.58	NS
A x B interaction	12	0.93	0.08	0.01	1.98	NS
Error	44	350.35	7.96			

ANOVA VI (b): Pooled analysis of variance on soil microbial population of bacteria at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	7.60	1.90	0.14	2.58	NS
Factor A	6	2.60	0.43	0.03	2.31	NS
Factor B	4	101.48	25.37	1.81	2.58	NS
A x B interaction	12	0.19	0.02	0.00	1.98	NS
Error	44	617.54	14.04			

ANOVA VI (c): Pooled analysis of variance on soil microbial population of bacteria at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.13	0.78	0.21	2.58	NS
Factor A	6	1.87	0.31	0.08	2.31	NS
Factor B	4	37.09	9.27	2.50	2.58	NS
A x B interaction	12	0.73	0.06	0.02	1.98	NS
Error	44	162.95	3.70			

ANOVA VII (a): Pooled analysis of variance on soil microbial population of PSB at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.62	0.15	0.53	2.58	NS
Factor A	6	0.17	0.03	0.10	2.31	NS
Factor B	4	2.66	0.66	2.29	2.58	NS
A x B interaction	12	0.03	0.00	0.01	1.98	NS
Error	44	12.74	0.29			

ANOVA VII (b): Pooled analysis of variance on soil microbial population of PSB at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.93	0.23	0.07	2.58	NS
Factor A	6	1.39	0.23	0.07	2.31	NS
Factor B	4	33.22	8.30	2.55	2.58	NS
A x B interaction	12	0.32	0.03	0.01	1.98	NS
Error	44	143.47	3.26			

ANOVA VII (c): Pooled analysis of variance on soil microbial population of PSB at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.99	0.25	0.35	2.58	NS
Factor A	6	0.51	0.09	0.12	2.31	NS
Factor B	4	7.25	1.81	2.53	2.58	NS
A x B interaction	12	0.05	0.00	0.01	1.98	NS
Error	44	31.56	0.72			

ANOVA VIII (a): Pooled analysis of variance on soil microbial population of fungi at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.14	0.03	0.27	2.58	NS
Factor A	6	0.24	0.04	0.32	2.31	NS
Factor B	4	1.28	0.32	2.52	2.58	NS
A x B interaction	12	0.03	0.00	0.02	1.98	NS
Error	44	5.59	0.13			

ANOVA VIII (b): Pooled analysis of variance on soil microbial population of fungi at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.63	0.41	0.39	2.58	NS
Factor A	6	1.00	0.17	0.16	2.31	NS
Factor B	4	10.42	2.60	2.49	2.58	NS
A x B interaction	12	0.39	0.03	0.03	1.98	NS
Error	44	46.01	1.05			

ANOVA VIII (c): Pooled analysis of variance on soil microbial population of fungi at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	0.89	0.22	0.53	2.58	NS
Factor A	6	0.30	0.05	0.12	2.31	NS
Factor B	4	4.32	1.08	2.57	2.58	NS
A x B interaction	12	0.03	0.00	0.01	1.98	NS
Error	44	18.45	0.42			

ANOVA IX (a): Pooled analysis of variance on soil microbial population of actinomycetes at 30 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	1.80	0.45	0.70	2.58	NS
Factor A	6	0.34	0.06	0.09	2.31	NS
Factor B	4	6.04	1.51	2.36	2.58	NS
A x B interaction	12	0.16	0.01	0.02	1.98	NS
Error	44	28.13	0.64			

ANOVA IX (b): Pooled analysis of variance on soil microbial population of actinomycetes at 60 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	3.21	0.80	0.40	2.58	NS
Factor A	6	1.10	0.18	0.09	2.31	NS
Factor B	4	20.81	5.20	2.56	2.58	NS
A x B interaction	12	0.22	0.02	0.01	1.98	NS
Error	44	89.36	2.03			

ANOVA IX (c): Pooled analysis of variance on soil microbial population of actinomycetes at 90 DAS in maize based intercropping system as influenced by planting geometry and weed management

Source of Variance	DF	S.S	M.S.S	F Cal	F Tab at 5%	S/NS
Replication	4	6.60	1.65	0.40	2.58	NS
Factor A	6	2.69	0.45	0.11	2.31	NS
Factor B	4	42.34	10.58	2.54	2.58	NS
A x B interaction	12	0.21	0.02	0.00	1.98	NS
Error	44	183.32	4.17			