EFFECT OF PLANTING PATTERN ON GROWTH, YIELD AND QUALITY OF PEARLMILLET (*Pennisetum glaucum* L.) + CLUSTERBEAN (*Cyamopsis tetragonoloba* L.) INTERCROPPING UNDER AGRI-HORTI SYSTEM OF VINDYAN REGION

THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Master of Science (Agriculture)
in
Agroforestry

Submitted by
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Affectionately Dedicated

to

My Beloved Parents

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CERTIFICATE

To,
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Through: The Head
Department of Agronomy
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Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of planting pattern on growth, yield and quality of pearlmillet (*Pennisetum glaucum* L.) + clusterbean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of vindyan region"**submitted by **Mr. Dan Singh**, I.D. No. AGF-10192, in partial fulfillment of the requirements for the degree of Master of Science (Agriculture**)** in **Agroforestry**.

I certify that the work has been carried out under my guidance and the data forming the basis of this thesis, to the best of our knowledge are original and genuine and no part of the work has been submitted for any other degree or dissertation.

Thanking you.

Yours faithfully

FORWARDED

(R. N. Meena)
Supervisor

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*I bow my head with great reverence in the pious feet to the founder of this University, **Mahamana Pandit Madan Mohan Malviyaji,** a man of great vision for creating such a wonderful and unique University, a temple of learning for thousand of students like me.*

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Date:
Place: Varanasi **(Dan Singh)**

CONTENTS

SYMBOLS AND ABBREVIATIONS

%	:	Per cent
/	:	Per
BC	:	Benefit and Cost
^{O}C	:	Degree celsius
C.D.	:	Critical difference
cm	:	Centimeter
DAS	:	Day after sowing
dsm^{-1}	:	Decisiemen per meter
EC	:	Electrical conductivity
ET	:	Evapotranspiration
et al	:	Et alibia
etc	:	Etceteras
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
hrs	:	Hours
i.e.	:	That is
Kg	:	Kilogram
Kg ha^{-1}	:	Kilogram per hactare
m	:	Meter
m t	:	Million tonnes
Max.	:	Maximum
m ha	:	Million hectare
Min.	:	Minimum
mm	:	Millimeter
No.	:	Number
pH	:	Puissance de hydrogen
q	:	Quintal
Rs ha^{-1}	:	Rupees per hectare
S.E.(m)±	:	Standard error of mean
Viz.	:	Namely
WUE	:	Water use efficiency

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Chapter-I

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) Br. Emend stuntz.] with a popular name *Bajra* ranks sixth in importance, followed by wheat, rice, corn, barley and sorghum. However, in India, it is fourth most important cereal crop after rice, wheat and sorghum. It has the greatest potential among all the millets. India is the largest producer of pearl millet with an annual production of 8.52 million tonnes from an area of 8.91 million ha and productivity of 9.57 q ha^{-1} (AICPMIP, 2008). It spread from there to East Africa and then to India. Today millet is a staple food for more than 500 million people. Areas planted with pearl millet are estimated at 15 million hectares annually in Africa and 14 million hectares in Asia. Global production exceeds 10 million tonnes a year (National Research Council, 1996).

Uttar Pradesh stands fourth in pearl millet production first in productivity *i.e.* 2.31 m t annually from 4.70 m ha in India. The average productivity is only 1492 kg ha^{-1} which is quite low (Anonymous, 1996-97). Weather aberrations have become a common feature of dry land agriculture in India. Efforts have been made for the last many decades to devise comprehensive contingency plan for augmenting crop production under changing weather conditions. Soil moisture Linchpin the success of crop production in dry land areas. The problem of deficient soil moisture is compounded by often highly erratic rainfall intensity and frequency, both accompanied by high evapo-transpiration and low moisture holding capacity of the soil. Early stoppage or long gap in monsoon rains in north western plain zone, generally encounters soil moisture deficit during critical growth stages of dry land crops.

The food value of pearl millet is high. Trials in India have shown that pearl millet is nutritionally superior from human growth when compared to maize and rice. The protein content of pearlmillet is higher than maize and has a relatively high vitamin A content. It is a dual purpose crop, its grain is used for human consumption and its fodder as cattle feed. Pearl millet is a small seeded caryopsis. The nutrient content of pearl millet compares very well with other cereals and millets. It has high protein content with slightly superior amino acid profile. Pearl millet grain contains 13-14 per cent protein, 5-6 per cent fat, 74 per cent carbohydrate and 1-2 per cent minerals. It also contains higher amount of carotene, riboflavin (Vit B_2) and niacin (Vit B_4).

Pearl millet is grown by millions of resource-poor, subsistence level farmers (IFAD, 1999). The percentage of millet used for domestic consumption is rising steadily in Africa (World Bank, 1996). Pearl millet, which accounts for about two-thirds of India's millet production, is grown in the drier areas of the country, mainly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana as they contribute approximately 85% of total pearl millet production (FAO, 1996). At present, it is grown in an area of about 10.0 m ha and account for 9.87% of the land under cereals. Its contribution to the nation's total cereal pool is nearly 4.27 % with a total production of 7.9 million tonnes (G.O.I., 1997-98).

Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] is being grown in India since ancient time for vegetable and fodder purposes. Among leguminous crops, it is comparatively more drought hardy crop. It is popularly known by its vernacular name '*Guar*' and it is grown during rainy season in semi arid and arid regions of India for various purposes *viz*., vegetables, green fodder, green manuring and seeds. In the recent years, besides its conventional uses, it has emerged as an industrial crop, due to presence of galactomannan (gum) in its endosperm, which is around 30-35 per cent of seed weight. Guar gum has several diversified uses in textile, food processing, cosmetics, mining, explosive, oil and pharmaceutical industries, printing, toilet goods etc. India occupies top position in the world trade for guar gum and earn crores of foreign exchange by its export. Guar meal, a byproduct of gum industries, forms concentrate animal feed for immense value, as it contains more than 42 per cent protein against 31 per cent in guar seed.

In India, area of cluster bean has increased rapidly in recent years due to establishment of gum industries. India enjoys a unique status in the cultivation of cluster bean in the world because of congenial climatic condition for crop growth. India occupies about three-fourth of the global cluster bean cultivation. Being deep rooted and drought hardiness, this crop has occupied sizeable areas in arid and semi-arid regions encompassing Rajasthan, Gujarat and Haryana state

Intercropping of cereals with legumes is an effective approach for boosting herbage yield, utilization of land efficiently and providing stability to production (Verma *et al*., 2005). Yield, utilization of land efficient and providing stability to production (Bezbaruah and Thakuria, 1996) pearl millet is an idea fodder crop, possessing quick growing and height-yield ability during summer. Intercropping of legumes in pearl millet was found more production and remunerative (Ram *et al*., 2005; Sharma, 2008) when compared with their sole. The types of intercrop and spatial arrangement in intercropping have important effect on balance of compaction between component crop and their of completion between component crop and their productivity (Sarkar and Pal, 2004). Hence, to get best result, a ratio approach row proportion of fodder pearl millet and legumes in intercropping system. Multiple cropping in the form of intercropping is predominant in the arid and semi-arid tropics. Intercropping is a feasible and viable option for stepping up the production of pulses and oilseed in our country. Cluster bean is a major rainfed crop of arid zone, grown mostly as a mixed crop with, moth bean, but its productivity is low (Faroda *et al*., 2007). Plant population and spatial arrangement in intercropping have important effect on the balance of completion between the component crop and their product. Intercropping of cereal and pulse crops is one of the ways to increase their production because intercropping is more advantage than sole cropping of either of these crop (Padhi and Panigrahi, 2006. The greatest limitation in increasing the productivity of these crops is inadequate supply of nutrient, because the soil of arid region are poor in native fertile (Singh and Khan, 2003.

Intercropping of cereals with legumes is an effective approach for boosting production and quality forage crop (Rao and Willey, 1980).Which is enriches the soil fertility (Benzbaruah and Thankuria, 1996). Pearl millet and cluster bean [*Cyamopsis tetragonoloba* (*L.*) Taub] are the potential fodder crops, which can provide good nutrition to livestock with higher fodder yields and improved fodder quality, when grown in association. Further, it may also be beneficial for improving the fertility status of the soil. Intercropping of cluster bean in pearl millet was found more productive and remunerative than pearl millet + cowpea or green gram (Ram *et al*., 2005). But the information on row proportions of multi-cut fodder pearl millet and cluster bean in intercropping system in hot arid region is not available. Therefore, present investigation was undertaken.

Agroforestry is a land use system which involves mixture of trees or other woody perennials with agricultural crop/ grass and /or animals simultaneously or sequentially. In general there are 4 or 5 basic sets of components in agroforestry system (Dhyani *et al*., 2009). Agri-horti system is one of the important components of agroforestry in which the integration of fruit crops in croplands is practiced. Aonla, ber, guava, citrus etc. are major promising fruit crop suitable for agri-horti system. Fruit crops are first preference of farmers under agroforestry system on account of short gestation period, regular income, risk cover and aesthetic value (Anon, 2000). Agri-horti system is an improved indigenous cropping system in India for full utilization of the growing season and markedly increasing the return per unit area per unit time.

In Vindyan region agricultural research station Rajiv Gandhi South Campus, BHU Barkachha most of the soils are red loam, character of red loam soil water holding capacity is less. Vindyan region growing of pulse crop intercropping with custard apple, guava, bael and aonla etc. are more suitable under the agri-horti system. Therefore, this study was undertaken to assess the productive, economics and quality of different intercropping system of pearl millet with legumes at different row proportion during summer season. Keeping above points in view the present study entitled **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of Vindyan region"** was planned with following objectives.

1. To find out the effect of intercropping treatment with different planting pattern on growth, yield and quality of pearl millet and cluster bean intercropping under agri-horti system of Vindyan region.

2. To assess the efficiency of pearlmillet and clusterbean intercropping system with different planting pattern

3. To work out the economics of different intercropping treatment.

Chapter-II

REVIEW OF LITERATURE

The review of literature on important aspects pertaining to the present study entitled **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of Vindyan region"** is presented in this chapter. An attempt has been made to cite the relevant literature on pearl millet - legume intercropping systems. These crops need less water and are more tolerant to drought salinity and alkali conditions than other *Kharif* crops. Besides these aspects relevant work on related crops has also been reviewed, wherever felt necessary.

2.1 Effect of intercropping systems

Intercropping of legume with cereals has become a common practice in traditional agriculture of dry lands but oilseed-legume intercropping is a recent concept, which has become feasible after development of new, early maturing and short duration cultivars. These cultivars, besides producing higher yields are more compatible as intercrops than earlier varieties (Singh and Jodha, 1989). The productivity of intercropping systems with larger intervals between harvests showed large and consistent advantage over narrow interval between harvests of component crops (Rao and Singh, 1990).

In India, pearl millet is also grown as an intercrop stand with legumes (cluster bean, green gram, black gram, horse gram, cowpea and soybean) and oilseed crops like groundnut and sesame (Jodha *et al.*, 1992).

Ram *et al.* (2005) Intercropping of cluster bean in pearl millet was found more productive and remunerative than pearl millet + cowpea or green gram. Verma *et al.*, (2005) intercropping of cereals with legumes is an effective approach for boosting herbage yield, utilization of land efficiently and providing stability to production. Padhi and Panigrahi (2006) reported that plant population and spatial arrangement in intercropping have important effect on the balance of completion between the component crop and their product. Intercropping of cereal and pulse crops is one of the ways to increase their production because intercropping is more advantage than sole cropping of either of these crops.

2.1.1 On growth parameters

Sharma *et al.* (1993) studied the compatibility of pearl millet, cluster bean and cowpea grown alone or intercropped. The sole pearl millet crop give the highest dry matter yield of 9.77 t ha^{-1} whereas, the cowpea grown alone gave the lowest dry matter yield of 4.29 t ha^{-1}. Ikramullah *et al.* (1996) while, working at Rajendranagar (Hyderabad) reported that plant height of sorghum was significantly higher in sole stand (173 cm) than intercropping system (163 cm).

Sharma (1997) conducted an experiment at Jobner (Rajasthan) on intercropping of cluster bean, cowpea and mung bean with pearl millet and reported that intercropping significantly enhanced plant height, dry matter accumulation and branches per plant of cluster bean, cowpea and mung bean at all the successive stages. Mandimba *et al.* (1998) conducted an experiment at Brazza Ville (Congo) on intercropping of groundnut with maize in 4:1 row ratio and observed that intercropping reduced the dry matter yield of groundnut.

Khateek *et al.* (1999) reported that intercropping increased plant height of pearl millet, decreased dry matter production and tiller number per plant and did not significantly affect yield components such as spike length and test weight. Ram *et al.* (2003) observed that the maximum plant height of pearl millet was recorded under sole pearl millet being at par with pearl millet + cluster bean, significantly higher compared to pearl millet intercropped with cowpea and green gram.

Yadav *et al*. (2005) while working at CAZRI, Bikaner showed that the highest dry matter production of moth bean and cluster bean with pearl millet intercropping was obtained under 5:1 and 6:1 planting system and were at par with 4:1 and 5:1 planting system. Rana *et al.,* (2006) reported that maize paired row (40/80 cm) + one row of mung bean recorded significantly higher cobs/plant, cob length, grains/cob, grain weight/cob compared to sole maize.

Pathak and Singh (2008) while working at Pantnagar showed that intercropping of maize with black gram in 1:1, 2:1 and 2:2 row ratio gave better growth in terms of number of branches and lateral spread under both monoculture and intercropping treatments with different planting patterns.

2.1.2 On yield and yield attributes

Bhadoria *et al.* (1992) observed at Gwalior that yield of cluster bean was significantly reduced by intercropping with pearl millet irrespective of genotype. Grain yield of pearl millet was also reduced significantly by intercropping it with cluster bean compared with sole crop of pearl millet.

Kumar and Gautam (1992) reported that biomass production was higher in pearlmillet intercropped with cowpea than with castor. Singh (1992) observed that N uptake by grain and straw and total uptake was maximum in pearl millet + cluster bean intercropping as compared to pearl millet + mung bean and pure stand of pearl millet. Kumar *et al.* (1993) observed increase in grain protein content in pearl millet under castor + pearl millet intercropping system

Yadav (1992) at Bikaner, Rajasthan conducted a trial on castor intercropping with cluster bean and green gram and reported that the seed yield of sole castor, castor + green gram and castor + cluster bean were 200, 180 – 262 and 132 – 248 kg ha^{-1}, respectively. Yields of cluster bean and green gram were more when grown as a sole crop as compared to intercropping systems.

Gupta and Rathore (1993) conducted a field experiment on salty loam soil to select a suitable rainy season crop for intercropping with castor and found that highest mean castor equivalent seed yield (25.16 q ha^{-1}) was obtained by intercropping two rows of green gram (*Vigna radiata*) in between the castor crop sown at one m row spacing. This was followed by castor + black gram (*V. mungo*) and castor + groundnut.

Hazara and Behari (1993) found that when pearl millet was grown in single or paired rows with cowpea or cluster bean, the legume yields compensated for the loss of pearl millet yield in the intercropped systems, increasing total green forage yield by 11-29 per cent and dry forage by 5-23 per cent over sole pearl millet. Reddy *et al.*

(1993) concluded from the intercropping studies on pigeon pea that pigeon pea yield was reduced when it was intercropped with cereals, millets and oilseed and the reduction was lowest with castor. Singh and Singh (1993) observed that the grain yield was increased by sowing of pearl millet between single or paired rows of pigeon pea over pure stands.

Goutam (1994) reported that performance of sole pigeon pea was significantly superior to sole pearl millet. Pearl millet + pigeon pea in 1:1 or 2:1 row intercropping proved as superior as compared to pigeon pea alone. Growing of pearl millet and pigeon pea as intercrops in paired row system in the ratio of 1:2 (30/60 cm) or 1:3 ratios produced higher dry matter in different parts of plant and pearl millet equivalent yield. These systems gave 10 q ha-1 grains of pearl millet along with 14 q ha-1 grains of pigeon pea. Singh and Joshi, (1994) working at Jodhpur (Raj.) observed that among the different intercropping systems pearl millet and cluster bean (1:1) gave the highest grain yield of pearl millet.

Arya and Niranjan (1995) while, working at Jhansi (U.P.) revealed that grain and straw yield was higher in the treatment of sole sorghum than intercropping systems.

Dubey *et al.* (1995) reported that grain and straw yield of sorghum was significantly more in sole stand than the intercropping systems. However, sorghum equivalent yield was higher under intercropping systems than pure stand of sorghum. Dubey *et al.* (1995) revealed that cob length, grain per cob, and test weight were maximum under the treatment of intercropping systems than sole sorghum. Similarly, Singh *et al.* (1995) in an experiment on sandy loam at Ranchi (Jharkhand) observed that grain yield of maize was significantly higher in the sole stand (4.31 t ha^{-1}) as compared to intercropping systems but sorghum equivalent yield was higher under intercropping systems due to additive yield of intercrops.

Tiwana and Tiwana (1995) at Bathinda (Punjab) found the highest total seed/grain yield in 3:1 cluster bean + pearl millet ratio. Ikramullah *et al.* (1996) observed that grain yield of sorghum was significantly more under sole cropping system as compared to intercropped with legumes. Sharma *et al.* (1996) while, working at Banswara (Raj) reported that grain yield of maize was highest in the sole maize system than maize + black gram intercropping system but maize equivalent yield was significantly more in the intercropping system than monocropping of maize. Saxena *et al.* (1997) observed that the pearl millet + cluster bean ratio and monoculture of pearl millet with the application of 5 t ha^{-1} FYM gave 17.2 and 6.1 per cent higher yield than monoculture of pearl millet, respectively. Singh and Joshi (1997) observed that row intercropping of pearl millet with cluster bean (1:1) and strip cropping (4:4) with 50 per cent of the sole pearl millet population produced 35.4 per cent lower pearl millet yield in the moisture season and 37.4 per cent lower pearl millet yield in the moisture stressed season.

Subrahmaniyam *et al.* (2000) in a field experiment at Vridhachalam (T.N.) observed that when groundnut was intercropped with red gram, green gram, sunflower and cowpea at 4:1 row ratio, intercropping of groundnut with red gram gave the highest groundnut and intercrop yield and net return. The GAUCH-4 variety of castor intercropped with cowpea, mung bean and cluster bean give be highest total equivalent yield of 1.72 t ha^{-1} in Jobner (Rajasthan) under rainfed conditions (Sharma, 2000). The GAUCH-4 variety of castor intercropped with cluster bean is the most suitable system of intercropping producing the equivalent yield of castor 1.82 tans ha^{-1} and net return Rs. 8416 ha^{-1} in Jobner (Rajasthan) under rainfed conditions of semi-arid tract (Balai, 2002).

Pandey *et al.* (2003) observed that the plant height was unaffected by intercropping system but yield attributing characters of maize decreased due to intercropping. Ram *et al.*, (2003) observed that the sole pearl millet gave significantly more ear length, grain per ear, grain (20.8 q ha^{-1}) straw (54.9 q ha^{-1}) and biological (75.6 q ha^{-1}) yield compared to rest of the intercropping systems, while highest pearl millet grain equivalent yield was recorded under pearl millet + cluster bean (39.1 q ha^{-1}), followed by pearl millet + mung bean over pearl millet + cowpea and sole pearl millet.

Pandy *et al.* (2003) at Pusa, Samastipur reported that intercropping system reduced the values of yield attributes and grain yield of maize than sole cropping of maize but significant reduction in cob length, kernels/row, grains/cob and grain yield were recorded only with sesamum, turmeric and forage moth intercropping systems. An experiment was conducted at Dharwad revealed that sole sorghum with different geometries recorded higher yield than sorghum intercropped with different legumes. However, sorghum intercropped with French bean, soybean and black gram were comparable with sole sorghum (Amedie *et al.,* 2004).

Singh *et al.* (2003) a field experiment was conducted in the *kharif* seasons to investigate the productivity of various planting geometries and intercropping systems reported that the treatments were cluster bean at 30 and 40 cm row spacing, and 30:60 cm paired row; 30:60 cm paired row + one row of green gram; 30:60 cm paired row + one row of pearl millet; pure green gram at 45 cm; and pure pearl millet at 45 cm. Mean cluster bean yield was highest (15.82 q/ha) under 30:60 paired row geometry, and this produced 0.9 and 0.7 q/ha more yield than 30 and 45 cm spacing, respectively. Intercropping with green gram and pearl millet decreased cluster bean yield by 19 and 27.2% compared to sole stand in paired row, but produced respective yields of ha^{-1} 2.27 and 8.69 q/ha. Intercropping with green gram was more profitable than the other intercropping treatment in terms of cluster bean equivalent yield (17.7 q/ha), net return (Rs. 6846/ha) and income equivalent ratio (1.9). Cluster bean + green gram showed higher values for land equivalent ratio, area time equivalent ratio, crowding coefficient and competition ratio compared to cluster bean + pearl millet

Singh and Agrawal (2004) observed that yield attributed (length of ear, grain weight/ear and 1,000 grain weight) of pearl millet were not influenced by intercropping system. Singh and Agrawal (2004) in a field experiment consisting intercropping of pearl millet with pigeon pea and castor reported that the N and P uptake by pearl millet was significantly influenced by cropping systems. The N and P uptake was maximum with sole pearl millet as compared to intercropping with pigeon pea and castor.

Dadhich and Gupta (2005) A field experiment was conducted in Jobner, Rajasthan, India, on loamy sand soil during the consecutive summer seasons of 1999-2000 with four levels of S (0, 20, 40 and 60 kg/ha), three levels of Zn (0, 5 and 10 kg/ha) and two planting pattern (sole pearl millet and pearl millet + cowpea in 3:1 row ratio) S at 40 kg/ha significantly increased plant height, tillers per plant, leaves per plant, stem girth and leaf area over the control at both the cuttings and in pooled mean, except for leaves per plant in first cutting, which increased only up to 20 kg S ha^{-1}. The pearl millet + cowpea intercropping proved significantly superior to sole pearl millet with respect to plant height, tillers per plant, leaves per plant, leaf area, green fodder yield and crude protein yield in both the cuttings and in pooled mean data, except plant height, leaves per plant and leaf area at second cutting.

Singh *et al.* (2005) reported that a field experiment was conducted during the *Kharif* season to evaluate cluster bean, green gram and pearl millet , cluster bean at 30, 45, 30:70 cm paired row, 30:70 cm paired row+one row of green gram, 30:70 cm paired row+one row of pearl millet; sole green gram at 30, 45, 30:70 paired row, 30:70 cm paired row+one row of cluster bean, 30:70 cm paired row+one row of pearl millet; and sole pearl millet at 30 and 45 cm. On mean basis, the highest seed yield of cluster bean (16.62 q ha^{-1}), green gram (6.32 qha^{-1}) and pearl millet (21.90 qha^{-1}) were recorded at 30:70 cm paired row, 45 cm and 30 cm row spacing, respectively. In cluster bean, paired row planting produced 0.5 and 0.8 qha^{-1} higher seed yield than 30 and 45 cm row spacing, respectively. Planting of cluster bean either in pure or intercropping with green gram and pearl millet was more productive and remunerative than sole and other intercropping systems of green gram and pearl millet

Sharma and Kulhari (2005) found that intercropping of castor with cluster bean, cowpea and mung bean were significantly reduced seed and stalk yield as compared to sole castor. They further, recorded that significantly higher seed and stalk yields under intercropping with cluster bean as compared to intercropping of castor with cowpea and mung bean.

Yadav and Jat (2005) reported that the three moth bean varieties namely RMO-40, Jwala and IPCMO-912 are intercropped in 1:2, 2:1, 2:2, 1:3 and 3:1 row ratios with pearl millet. The result revealed that the short duration moth bean variety RMO-40 recorded significantly higher grain yield in intercropping with pearl millet than that obtained from Jwala and IPCMO-912, however. IPCMO-912 being at par with long duration Jwala gave significantly higher fodder yield than RMO-40 in the intercropping system. Yadav and Jat (2005) reported that the row ratio of 2:1 moth bean : pearl millet being at par with 3:1 produced significantly higher grain and straw yields of moth bean in intercropped system than other ratios. Significantly higher pearl millet grain yield was recorded in 1:3 (moth bean: pearl millet) row ratio but it was at par with 1:2 (moth bean: pearl millet) row ratio. The highest fodder yield of pearl millet was recorded in 1:3 ratio compared to all other ratios.

Yadav *et al*. (2005) while working at CAZRI, Bikaner showed that the highest grain yield of moth bean and cluster bean with pearl millet intercropping was obtained under 5:1 and 6:2 planting system and were at par with 4:1 and 5:1 planting system.

Hosaini *et al.,* (2006) to evaluate the effect of different planting arrangements on forage yield of pearl millet (*Pennisetum glaucum* cv. Nutrified) and cowpeas (*Vigna unguiculata* cv. Parastoo) in intercropping, a research was conducted at the Research Farm, College of Agriculture, Tehran University (Iran) during the year of the 2003. Pure stand treatments (MMMM=pure stand of forage pearl millet, CCCC=pure stand of cowpea), replacement mixed treatments (MC=1:1 ratio MMCC=2:2, MMMCCC=3:3) and additive mixed treatments (MC20%=100% forage pearlmillet+20% cowpea, MC10%=100% forage pearlmillet+10% cowpea) were examined. The results showed that the MC20% treatment produced the most forage yield per hectare of pearl millet. The cowpea in the intercropping system was not predominant and its yield was higher when it was in pure stand. The results of yield per plant showed the predominance of forage pearl millet. Calculation of land equivalent ratio (LER) also showed that in additive mixed cropping, the yield of MC20% treatment was 32% higher than that of its pure stand (LER=1.32). It is concluded that intercropping systems uses environmental factors better than monocultures.

Kumar *et al.* (2006) reported that a field experiment was conducted during *Kharif* seasons of 2002 and 2003 at Hisar showed that sole pearl millet, cluster bean, mung bean, cowpea and black gram were gave significantly higher grain and straw yields over inter and strip-cropping Padhi and Panigrahi, (2006). Plant population and spatial arrangement in intercropping have important effect on the balance of completion between the component crop and their product. Intercropping of cereal and pulse crops is one of the ways to increase their production because intercropping is more advantage than sole cropping of either of these crops. Singh *et al.* (2006)

reported that maximum pearl millet grain yield was recorded with pearl millet (paired row) + soybean (2:1) followed by pearl millet (uniform row) + soybean (2:1) followed by pearl millet (uniform row) + soybean (1:1). Tetarwal and Rana (2006) while working at New Delhi reported that the planting of one row of moth bean between paired rows of pearl millet proved superior to sole pearl millet in respect of pearl millet equivalent yield, water use efficiency and economics. Soni *et al*. (2007) showed in an experiment that the grain and straw yield of cluster bean and moth bean was more in strip cropping with grass over their sole cropping. The highest cluster bean equivalent yield was recorded with grass + cluster bean (5:15 m) strip cropping system.

Singh *et al.* (2006) reported that a field experiment was conducted during *Kharif* seasons to study the effect of different planting patterns on the yield and yield attributes in soybean and pearl millet intercropping system. The experiment comprised eight different treatment combinations of row proportions of component crops, soybean and pearl millet (i.e. sole soya bean; sole pearl millet; soybean paired row; soy bean + pearl millet at either 2:1, 3:1 or 4:1; soybean (paired row)+ pearl millet at 2:1; and soy bean + pearl millet at 4:2). Intercropping soybean with pearl millet at the ratio of 2:1 was the best based on the combined productivity (equivalent yield) i.e. 2893 and 2182 kg ha^{-1} for soybean and 5280 and 4247 kg ha^{-1} for pearl millet during 2003 and 2004, respectively, compared to other intercropping systems and sole crop of soybean. Sole crop of pearl millet gave the highest grain yield over the other treatments, but among the intercropping systems, the single row of pearl millet with two rows of soybean gave a higher grain yield. The yield attributes, pod density in soybean and number of fertile tillers in pearl millet were also higher in the 2:1 intercropping system compared to the other treatments.

Girase *et al.* (2007) reported that A field experiment was under rainfed conditions during *Kharif* in season, involving 8 treatments: sole pearl millet (*P. glaucum*), sole moth bean [*Vigna aconitifolia*], sole horse gram [*Macrotyloma uniflorum*], sole cowpea, pearl millet + moth bean (2:1), pearl millet + horse gram (2:1), pearl millet + cow pea (2:1), and pearl millet + horse gram (4:2). The intercropping of pearl millet + moth bean at 2:1 row ratio resulted in significantly higher pearl millet grain equivalent yield (36.62 q ha-1) than all the other intercropping systems and sole cropping, however, it was at par with pearl millet + cow pea (33.56 q ha^{-1}). Similarly, the highest net monetary returns (Rs. 14 617 ha-1), benefit-cost ratio (2.98) and land equivalent ratio (LER, 1.47) were recorded in the pearl millet + moth bean intercropping system. Pearl millet equivalent yield, net monetary returns and LER showed that pearl millet + moth bean (2:1) or pearl millet + cow pea (2:1) appeared the most productive, efficient and profitable for rainfed conditions of the scarcity zone of north Maharashtra. Paroda *et al*. (2007) Cluster bean is a major rainfed crop of arid zone, grown mostly as a mixed crop with, moth bean, but its productivity is low.

Chauhan *et al.* (2008) reported that the grain yield of cluster bean decreased in intercropping system when compared with the yield obtained in pure stand whereas cluster bean equivalent yield was higher with 6:1 row ratio of cluster bean and pearl millet. In another study, five intercropping combinations of moth bean and pearl millet along with sole crop of moth bean and pearl millet were sown. The overall sole crop of moth bean produced significantly maximum pearl millet equivalent grain yield than rest of the combinations, however, it remain at par with moth bean: pearl millet intercropping at 3:1 ratio. Straw yield was maximum in moth bean: pearl millet intercropping at 1:3 ratio followed by 1:2 ratio treatments (Kandpal *et al.,* 2008). Nanwal and Hooda (2008) field studies were conducted in Haryana, India, during the 2002 and 2003 *Kharif* seasons, to assess and evaluate the effect of sole, inter and strip cropping systems of pearl millet with legumes on crop productivity and soil health. Sole pearl millet and various legumes (cluster bean, mung bean, cowpea and black gram) recorded significantly higher grain yield than inter and strip cropping systems. Economic analysis of various inter, strip and sole cropping systems in terms of pearl millet yield equivalent revealed strip cropping of pearl millet + cluster bean (6:3) to be most remunerative

Meena *et al.* (2008) reported that effect of planting pattern on sustainability of cluster bean (*Cyamopsis tetragonoloba* L.) + sesame (*Sesamum indicum* L.) intercropping system under arid condition. Treatments comprised of 15 combinations of cropping systems, *viz*. sole cluster bean, sole sesame, cluster bean + sesame in 1:2, 1:1 and 2:1 row proportions and nutrient management, viz. the control, 40 kg N ha^{-1} and 20 kg N+5 t FYM ha^{-1}. Intercropping declined the seed yield of cluster bean by 30% compared to sole crop (mean of 3 years 0.71 t ha^{-1}). However, cluster bean-equivalent yield (0.92 t ha^{-1}), net returns (Rs. 6,251 ha^{-1}) and benefit: cost (B:C) ratio (1.67) were higher with cluster bean + sesame (2:1) intercropping system over the corresponding values of 0.71, 3,572 and 1.41 in sole cluster bean. Irrespective of the cropping system, application of 20 kg N+5 t FYM ha^{-1} recorded significantly higher cluster bean-equivalent yield (1.036 t ha^{-1}), net monetary returns (Rs. 7,793 ha^{-1}) and B:C ratio (1.79) than of 40 kg N ha^{-1} alone and the absolute control. Addition of 5 t FYM ha^{-1} along with 20 kg N ha^{-1} gave 8.5 and 9.8% higher uptake of N than of 40 kg N/ha and the control respectively. The sustainable yield index (SYI) and sustainable value index (SVI) were higher with cluster bean + sesame under 2:1 row ratio (0.74, 0.76), and the highest SYI (0.81) and SVI (0.82) indices were observed under the application of 20 kg N ha^{-1} with 5 t FYM ha^{-1}. Cluster bean + sesame (2:1) with application of 20 kg N+5 t FYM ha^{-1} was more advantageous and saved 50% recommended dose of N fertilizer.

Sharma *et al.* (2008) reported that a field experiment was conducted during rainy (*Kharif*, to determine the most compatible row ratio for pearl millet and legume inter/strip cropping system. Sixteen treatments comprising sole pearl millet (*Pennisetum glaucum*), cluster bean (*Cyamopsis tetragonoloba*), green gram and cowpea in 45 cm rows along with inter/strip cropping of pearl millet with cluster bean, green gram and cowpea in 2:1, 4:2, 6:3 and 8:4 rows 30 cm apart. Inter/strip cropping of legumes (green gram, cluster bean and cowpea) in 2:1 to 8:4 row ratio had no significant adverse effect on grain yield of pearl millet compared to the sole planting. Legume intercrops with pearl millet produced higher yield under wider strips (8:4 or 6:3 row ratios) compared to narrow strips (4:2 or 2:1 row ratio). Pearl millet + green gram strip-cropping in 8:4 or 6:3 row ratio was statistically at par to sole green gram, pearl millet + green gram in 4:2 and pearl millet +cow pea in 8:4 row ratio. The net returns (Rs. 4832/ha), benefit: cost ratio (1.43), monetary advantage index (1115) and income equivalent ratio (7.57) were highest under strip-cropping of pearl millet and green gram in 8:4 row ratio, closely followed by 6:3 ratio. Higher values of land equivalent ratio, area-time equivalent ratio, aggressivity, competition ratio and crowding co-efficient of green gram and cowpea intercrops in 8:4 and 6:3 strip-cropping systems with pearl millet showed their superiority over other inter/strip-cropping systems.

Sharma *et al.* (2009) a field experiment was conducted during the summer seasons of 2007 and 2008 at Sabour to assess the productivity and economics of intercropping of forage pearl millet [*Pennisetum typhoides* (L.) R. Br. Emend & Stuntz.] with cowpea [*Vigna unguiculata* (L.) Walp.], cluster bean [*Cyamposis tetragonaloba* (L.) Taub.] and rice bean [*Vigna umbellata* (Thumb) Ohwi and Ohashi] under 4 row proportions, *viz.*, 1:1, 1:2, 2:1 and 2:2. Fodder yields of both the component crops were substantially reduced under intercropping system compared with their sole stands. Pooled analysis of 2 years showed that pearl millet + cow pea (2:2) recorded significantly crude protein yield (1.36 t ha^{-1}).

2.1.3 On quality, nutrient content and uptake

Singh (1992) observed that N uptake by grain and straw and total uptake was maximum in pearl millet + cluster bean intercropping as compared to pearl millet + mung bean and pure stand of pearl millet. Kumar *et al.,* (1993) observed increase in grain protein content in pearl millet under castor + pearl millet intercropping system.

Ikramullah *et al.* (1996) reported that nitrogen uptake by sorghum crop was significantly more in sole sorghum (179 kg ha^{-1}) than intercropping system (157 kg ha^{-1}). Mishra *et al.,* (1997) reported the highest crude protein yield in paired alternate rows of sorghum with cowpea (2:2) as compared with other sole and intercropping systems of fodder sorghum, cowpea and horse gram.

Hooda *et al.* (2005) an investigation was undertaken on a well-drained sandy loam soil in Hisar, Haryana, India during the *Kharif* seasons of 2002 and 2003 to assess the effects of sole, inter- and strip-cropping systems of pearl millet with legumes on protein content and yield. The treatments comprised sole pearl millet (PM), cluster bean (CB), mung bean (MB), cowpea (CP), black gram (BG), PM+CB, PM+MB, PM+CP and PM+BG, each at 2:1, 4:2 and 6:3 ratios. Sole pearl millet recorded significantly the highest protein yield (125.1 and 123.33 kg/ha, respectively) than inter (2:1) and strip (4:2) and (6:3) cropping systems during 2002 and 2003. Among the legumes, the highest protein content (10.31%) was recorded in strip-cropping of pearl millet with cowpea in 6:3 ratio. However, the highest protein yield was recorded in sole mung bean (119.27 kg/ha) and sole cluster bean (73.70 kg/ha) during the first and second year, respectively.

Kumar *et al.* (2005) observed that significantly higher total crude protein was recorded with maize + cowpea (2:2) indicating superiority of 35.5 and 68.9 per cent over sole stands of maize and cowpea, respectively. Further, total crude protein yield was equal in cowpea (sole), maize + cowpea (1:1 and 1:2) as well as with maize + cowpea (3:3 and 4:1). Singh (1997) observed that the uptake of N and P_2O_5 was significantly higher with intercropping than with sole cropping.

Girase *et al.* (2007) A field experiment was undertaken under rainfed conditions during the *Kharif* season of 2003 and 2004 in Dhule, Maharashtra, India, involving 8 treatments: sole pearl millet (*P. glaucum*), sole moth bean [*Vigna aconitifolia*], sole horse gram [*Macrotyloma uniflorum*], sole cow pea, pearl millet + moth bean (2:1), pearl millet + horse gram (2:1), pearl millet + cowpea (2:1), and pearl millet + horse gram (4:2). The intercropping of pearl millet+ moth bean at 2:1 row ratio resulted in significantly higher pearl millet grain equivalent yield (36.62 q ha^{-1}) than all the other intercropping systems and sole cropping, however, it was at par with pearl millet + cowpea (33.56 q ha^{-1}). Similarly, the highest net monetary returns (Rs 14 617 ha^{-1}), benefit-cost ratio (2.98) and land equivalent ratio (LER, 1.47) were recorded in the pearl millet + moth bean intercropping system. Pearl millet equivalent yield, net monetary returns and LER showed that pearl millet + moth bean (2:1) or pearl millet + cow pea (2:1) appeared the most productive, efficient and profitable for rainfed conditions of the scarcity zone of north Maharashtra. The cereal + legume intercropping system has still not been understood adequately as compared to sole cropping in terms of system efficient, more so regarding the concept of nutrient management where both crops have different growth habits and input requirements (Kimaro *et al*., 2009 and Mayaka *et al*., 2006).

An experiment was conducted at Pali during *Kharif* season of 2005 revealed that the nitrogen uptake was maximum under sorghum + mung bean with 2:1 row ratio at 50 kg N/ha and with same row ratio (Rao *et al.,* 2009).

Sharma *et al.* (2009) conducted an field experiment during the summer seasons of 2007 and 2008 at Sabour to assess the productivity and economics of intercropping of forage pearl millet [*Pennisetum typhoides* (L.) R. Br. Emend & Stuntz.] with cow pea [*Vigna unguiculata* (L.) Walp.], cluster bean [*Cyamposis tetragonaloba* (L.) Taub.] and rice bean [*Vigna umbellata* (Thumb) ohwi and ohashi] under four row proportions, *viz.*, 1:1, 1:2, 2:1 and 2:2. Fodder yields of both the component crops were substantially reduced under intercropping system compared with their sole stands. Pooled analysis of two years showed that pearl millet + cow pea (2:2) recorded significantly higher total green (52.8 t/ha), dry fodder yield (13.24 t/ha).

2.1.4 Economics and indices

Gadhia *et al.* (1993) reported that the pearl millet equivalent grain yield (4.86 t ha^{-1}) was highest when pearl millet was intercropped with pigeon pea in a 2:1 ratio and net return was also highest. Singh and Singh (1993) reported that the grain yield of maize in both the years was the highest in paired sowing (sole) but the total grain equivalent of maize was the highest in paired sown maize + French bean in ratio of 1:2. This also gave the highest net return (Rs. 10032 ha^{-1}) and monetary advantage (Rs. 11941 ha^{-1}) followed by paired sown + lentil in ratio 1:3. Singh, (1994) conducted an experiment in arid zone at Mandor- Jodhpur and reported that 4:4 ratio of pearl millet + moth bean gave significantly higher land equivalent ratio (LER) and net return as compare to sole pearl millet and 4:3, 4:2 row ratio.

Kalaghatagi *et al.* (1995) obtained higher LER of 2.02 with intercropping of pearl millet +pigeon pea in the row proportion of 4:2 followed by 1.68 with 1:1. The lowest LER (1.14) was recorded with pearl millet + groundnut at 3:3 row ratio. Aher *et al*. (1996) conducted a field experiment on intercropping systems at Dhule (Maharashtra) and reported that pearl millet + moth bean intercrop produced the highest seed yield, land equivalent ratio (1.32) and the highest gross returns.

Rafey and Prasad (1996) while working at Ranchi reported that the association of 100% population of sorghum and 75% population of black gram accounted for maximum land equivalent ratio as well as grain yield. However this treatment was very close to the stand of each component species with 100% population for all the parameters of evaluation. Yakadri *et al.* (1997) reported that pearl millet equivalent yield were highest in the sole crops than intercropping systems. Daulay *et al.* (1998) reported that mixed cropping and intercropping systems had higher total productivity than the pure stands and land equivalent ratio ranged from 1.00 to 1.46

Patel *et al.* (1998) observed that on the basis of net realization, CBR and LER, pearl millet intercropped with cluster bean with a row ratio of 2:1 was superior among different intercropped treatments. A field experiment was conducted during the rainy seasons at New Delhi revealed that the significant reductions in tillers/meter row length and dry matter per plant were observed in pearl millet + cowpea and pearl millet + sesamum intercropping. Yield attributes and grain yield recorded in pearl millet + pigeon pea, pearl millet + groundnut and pearl millet + cowpea did not differ significantly from sole pearl millet at 60 cm uniform row spacing. Maximum pearl millet grain equivalent was however, recorded with pearl millet + pigeon pea intercropping (Ramula *et al.,* 1998).

Joshi (1999) observed at CAZRI that the component density combination of 13.3 plants m^{-1} of pearl millet with 5 plants m^{-1} of mung bean was optimum and resulted in the highest grain yield, LER and WUE. A field experiment was conducted in Uttar Pradesh, India during the rainy seasons. It revealed that the yield, land equivalent ratio, maize equivalent yield and economic returns of a mixed stand of maize and black gram within 80 cm row spacing were superior to those of sole and other intercropping system (Singh, 2000).

Yadav and Yadav (2000) observed that the choice of the cropping system had significantly affected seed yield of both crops. Maximum grain yield of 2056 kg ha^{-1} was obtained in sole cropping of pearl millet (HHB-67) and it was significantly superior to mixed cropping treatments. Seed yield of pearl millet was reduced by in mixed cropping. They further reported that there were also differences in cluster bean seed yields obtained in pure and mixed stands with pearl millet. The seed yield of cluster bean (RGC-936) was reduced by 38-67% in mixed stands. They also reported that mixed cropping of pearl millet + cluster bean in 1:2 ratio gave significantly higher pearl millet equivalent yield.

Chosh *et al.* (2001) reported that the duration of component crop, their growth rate, planting density, the differences in the depth of rooting, lateral root spread and root densities are some of the factors that affect competition between the component crops in intercropping system for moisture and nutrient, and hence input use efficiency. It has been well documented that an import N-transfer take place in intercropping systems of legumes with cereal and this forces the legume component to fix more N_2 more N_2 from the atmosphere.

Padhi (2002) revealed that studies on maize legume based intercropping demonstrated that maize + black gram at 1:1 row ratio was found to be more productive, economically and energetically viable system with the highest maize-equivalent yield, net return, return/ rupee invested, land equivalent ratio, area time equivalent ratio, relative value total, relative net return, monetary advantage index, energy output and energy use efficiently for main and total produce.

Yadav and Beniwal (2003) while working at Bikaner found that highest land equivalent ratio was obtained at pearl millet: moth bean at 1:1 planting system followed by intercropping with cluster bean. Results showed that cluster bean had a more competitive effect on pearl millet compared to moth bean. The competitive ratio with moth bean as intercrop was highest at 1:1 ratio, while the competitive ratio with cluster bean was highest (4.36) at 2:2. Kumar *et al.* (2005) reported that significantly highest land equivalent ratio (1.41) in intercropping of maize and cowpea planted in row ratio of 2:2 followed by maize + cowpea in 2:1 row ratio (1.21) over all other intercropping systems of maize + cowpea in different row ratio. Similarly, mean gross returns, net returns and benefit: cost ratio were also significantly higher with maize + cowpea (2:2) then all other treatment of intercropping systems of maize and cowpea as well as sole crops of maize and cowpea.

Daulay *et al.* (2006) the compatibility of four promising varieties each of moth bean (T-8, JMM-259, Jwala and Jadia) and cowpea (FS-68, Charodi-1, C-152, and

JC-10) were evaluated for inter/mixed cropping with pearl millet for four consecutive years (1983-86) in Rajasthan, India. In inter/mixed cropping of moth bean varieties with pearl millet, the variety JMM-259 gave the higher total productivity and land equivalent ratio (LER) when it was grown in intercropping system. In case of mixed cropping system, variety T-18 gave at par performance with JMM-259. In case of cowpea varieties, variety Charodi-1 performed the best in all the cropping systems, viz., pure, inter- and mixed cropping, giving the highest total productivity. The LER with variety Charodi-1 was the maximum in mixed cropping system. However, it was variety C-152 which indicated higher magnitude of LER in intercropping system

Hosaini *et al.* (2006) to evaluate the effect of different planting arrangements on forage yield of pearl millet (*Pennisetum glaucum* cv. Nutrified) and cow pea (*Vigna unguiculata* cv. Parastoo) in intercropping, a research was conducted at the Research Farm, College of Agriculture, Tehran University (Iran) during the year of the 2003. Pure stand treatments (MMMM=pure stand of forage pearl millet, CCCC=pure stand of cowpea), replacement mixed treatments (MC=1:1 ratio MMCC=2:2, MMMCCC=3:3) and additive mixed treatments (MC20%=100% forage pearlmillet+20% cowpea, MC10%=100% forage pearlmillet+10% cowpea) were examined. The results showed that the MC20% treatment produced the most forage yield per hectare of pearl millet. The cowpea in the intercropping system was not predominant and its yield was higher when it was in pure stand. The results of yield per plant showed the predominance of forage pearl millet. Calculation of land equivalent ratio (LER) also showed that in additive mixed cropping, the yield of MC20% treatment was 32% higher than that of its pure stand (LER=1.32). It is concluded that intercropping systems uses environmental factors better than monocultures. Padhi and Panigrah (2006) from Orissa reported that intercropping system of maize + black gram at 1:1 row ratio significantly achieved the maximum maize grain equivalent yield, land equivalent ratio, area- time equivalent ratio and energy output compared to sole maize and black gram.

Rathore *et al.* (2006) Field experiments were conducted in Rajasthan, India, during the 1998, 2000 and 2001 *Kharif* seasons, on a loamy sand soil, to determine an arid legume suitable for intercropping in pearl millet and an appropriate intercropping system to sustain crop productivity and monetary returns. Two arid legumes *i.e.* cluster bean (*Cyamopsis tetragonoloba*) and moth bean (*Vigna aconitifolia*) were taken. There were six intercropping systems (pearl millet: legume row ratios) *i.e.* 1:1, 1:2, 2:1, 2:2, 4:2 and 2:4, along with the sole crops. Cluster bean was more suitable for intercropping in pearl millet as it gave higher mean pearl millet equivalent yield (1351 kg/ha), LER (1.01) and gross monetary returns (Rs. 7454/ha). Intercropping system 2:4 (pearl millet: legume) recorded higher pearl millet equivalent yield, LER and gross monetary returns. Moth bean can only be sown with a 2:4 row ratio.

Singh *et al.* (2006) reported that intercropping of pearl millet (paired row) with soybean in 2:1 followed by 1:1 row ratio was more remunerative then sole and other intercropping systems under rainfed conditions of semi-arid region of U.P. Bharati *et al.* (2007) while working at Pusa, Bihar revealed that intercrops with maize recorded significantly higher maize- equivalent yield than sole cropping of maize.

Sharma *et al.* (2009) a field experiment was conducted during the summer seasons of 2007 and 2008 at Sabour to assess the productivity and economics of intercropping of forage pearl millet [*Pennisetum typhoides* (L.) R. Br. Emend & Stuntz.] with cow pea [*Vigna unguiculata* (L.) Walp.], cluster bean [*Cyamposis tetragonaloba* (L.) Taub.] and rice bean [*Vigna umbellata* (Thumb) ohwi and ohashi] under 4 row proportions, *viz.*, 1:1, 1:2, 2:1 and 2:2. Fodder yields of both the component crops were substantially reduced under intercropping system compared with their sole stands. Pooled analysis of 2 years showed that pearl millet+ cowpea (2:2) recorded significantly crude protein yield (1.36 t/ha).

Chapter-III

MATERIAL AND METHODS

A field experiment entitled was entitled **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of vindyan region"** conducted at the research farm Rajiv Gandhi South Campus, (Banaras Hindu University) Barkachha, Mirzapur, Uttar Pradesh during *Kharif* 2011. The details of experiment techniques, materials used and methods/techniques adopted for treatment evaluation during the course of investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out at field number 12 of the Agriculture Research Farm situated at Rajiv Gandhi South Campus, (B.H.U.), Barkachha Mirzapur (U.P.) during *Kharif* season of 2011. The research farm is situated at a distance of about 11 km in South-East from Mirzapur on Mirzapur-Robertsgunj road. The district Mirzapur lies in the tropical, subtropical to dry Vindhyan region of Uttar Pradesh and it is a part of the Vindhyan soil (red laterite). Geographically, experimental site falls under the sub-tropical zone and located on 25º 10' latitude, 82º 37' longitude and altitude of 427 meters above mean sea level. According to "Agro-ecological region map" brought out by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). It is occupying over an area of more than 1000 ha where variety of crops like agricultural, horticultural, medicinal and aromatic plants are grown. Vindhyan soil comes under rainfed and invariably poor fertility status. This region comes under agro-climatic zone III A (semi-arid eastern plain zone).

3.2 Climate and weather

The climate of Barkachha is typically semi-arid, characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. Maximum temperature in summer is as high as 39.65˚C and minimum temperature in winter falls below 8.12˚C. The annual rainfall of locality was 774.7 mm in 2011, of which nearly 90 per cent is contributed by South West monsoon between July to September.

The rainfall during the experimental period was recorded from the meteorological observatory of the (KVK) Horticultural farm. The total rainfall during the crop season was 1080 mm; maximum and minimum temperature fluctuated between 34.7°C and 16°C and relative humidity between 90 and 33 per cent. The metrological data of Mirzapur district is given in Table 3.1

Table 3.1: Mean weather data: 50 year mean (1961-2011)

Month	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Sunshine hours	Evaporation (mm)
		Max.	Min.	Max.	Min.	Max.	Min.
January	2.7	19.96	8.12	86.20	42	6.04	1.74
February	1.3	26.97	12.45	84.75	44	8.43	2.55
March	0.68	32.2	16.13	73.33	28	8.90	4.13
April	1.44	35.86	20.72	58.4	23.6	9.38	5.7
May	2.85	39.65	26.45	64	26.75	9.08	8.3
June	59.06	35.68	27.2	71.8	50	6.88	7.2
July	50.36	32.54	27.08	84.2	70.4	4.70	3.88
August	73.15	31.17	26.65	88.5	76	5.35	3.3
September	75.15	30.8	26.45	89.25	74	6.20	2.92
October	0.72	31.66	20.72	84.6	45.6	7.75	2.9
November	0.21	28.97	15.1	90.75	39.75	8.0	2.6
December	0.32	21.77	9.75	94	54.75	6.48	1.42

Source: All India Co-ordinate Research Project on Dryland Agriculture.

The temperature begins to rise from the month of February and reaches its maximum in May. The mean minimum and maximum relative humidity in this region ranged between 72 and 82 per cent from July to September (Table-3.2)

Table3.2: Mean week-wise meteorological data during crop season *Kharif*, 2011.

Standard Weeks (SW)	Month	Date	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Evapo ration (mm)
				Max.	Min.	Max.	Min.	
28	July	09-15	6.2	34.7	28.3	79	59	5.2
29		16-22	114.2	31.5	26.4	88	77	2.4
30		23-29	39.6	32	26.5	85	69	3.7
31		30-05	41.8	30.8	27.4	88	81	3
32	August	06-12	183	28.9	25.8	90	85	2
33		13-19	106.6	30.3	26	88	82	2.4
34		20-26	52.8	33	27.4	88	68	3.4
35		27-02	61.1	32.5	27.4	84	69	4.9
36	September	03-09	44	32	26.2	88	71	3.4
37		10-16	28.6	30.5	26.3	88	77	3
38		17-23	68.8	30.7	29	93	74	2.7
39		24-30	296.4	30	24.3	88	74	2.6
40	October	01-07	25.2	31.1	23.8	84	55	3.6
41		08-14	3.8	33.1	23.5	83	49	5
42		15-21	3.6	31.7	20.4	84	38	2.9
43		22-28	4.3	31.6	19.9	84	53	2.6
44		29-04	0	30.8	16	88	33	2.5

Observatory:- Krishi Bhawan Mirzapur.

3.3 SOIL OF THE EXPERIMENTAL FIELD

The soil experimental site was typical red lateritic falling under the textural class of sandy loam. The soil was red and slightly acidic with moderate to low level of fertility. Before the start of the experiment, composite soil samples (0-15 cm depth) were randomly collected with the help of soil auger and core sampler. The soil samples were then subjected to mechanical and chemical analysis. The result, thus obtained has been presented in Table 3.3.

3.4 CROPPING HISTORY OF EXPERIMENTAL FIELD

The crop sequences followed in the experimental field during the past five years have been presented in Table 3.4. The cropping history of the experimental site clearly indicates that the field was not cropped continuously and kept fallow during two consecutive *Kharif* 2005 -2006 and *Rabi* seasons 2006 to 2008 and followed by the year 2008 to 2011 continuously cultivation the crop. During 2011-12 Pearl millet-cluster bean sequence was taken thus, the fertility set up has not been disturbed. Hence, as such the field is ideally suitable for the experiment.

3.5 EXPERIMENTAL DETAILS

The field experiment was laid out during *Kharif* season of 2011 in 5-year old guava which were planted at a spacing of 5 x 5 meter. Three annual crops, *viz*. sesamum, black gram and mung bean were sown as intercrops and sole crops. The experiment was conducted in randomized block design. Experiment was consisted total six treatment combinations replicated thrice (Table 3.5, 3. 6, & 3.7).

Table 3.3: Mechanical and physico-chemical analyses of soil of the experimental field.

Particulars	Value	Method	Reference
1. Mechanical analyses –			
Sand (%)	10.0	Hydrometer	Bouyoucos (1962)
Silt (%)	54.8		Bouyoucos (1962)
Clay (%)	35.2		Bouyoucos (1962)
Textural class	Sandy loam	Textural triangle	Black *et al.* (1965)
2. Physical analysis –			
Bulk density (Mg/M^{-3})	1.45	Pycnometer core sample	Black *et al.* (1965)
Particle density (Mg M^{-3})	2.65		Black *et al.* (1965)
Field capacity (%)	19.13	Field method	(Piper, 1966)
3. Chemical analysis			
Organic carbon (%)	0.23	Walkley and Black's	Jackson (1965)
Available N (kg/ha)	175.50	Alkaline permanganate	Subbiah & Asija (1956)
Available P_2O_5 (kg/ha)	10.15	0.5*N* $NaHCO_3$ extractable	Olsen *et al*. (1954)
Available S (kg/ha)	8.10	0.15% $CaCl_2$ extractable	Chesnin and Yien (1950)
pH (1:2.5 soil: water suspension)	5.9	Glass electrode digital pH meter	Jackson (1965)
Electrical conductivity (1:2.0 Soil:water suspension) dS/m at 25 ºC)	0.30	Systronics electrical conductivity meter	Jackson (1965)

Table 3.4 : Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2006-07	Fallow	Fallow
2007-08	Fallow	Fallow
2008-09	Mung bean	Mustard
2009-10	Mung bean	Mustard
2010-11	Cluster bean	Mustard
2011-2012	Experimental crop	-

Table 3.5 : Details of treatments and abbreviations used

S. No.	Treatment combinations	Symbols
1.	Pearl millet sole	T_1
2.	Cluster bean sole	T_2
3.	Pearl millet + cluster bean at 2:1 row ratio	T_3
4.	Pearl millet + cluster bean at 4:1 row ratio	T_4
5.	Pearl millet + cluster bean at 6:1 row ratio	T_5
6.	Pearl millet + cluster bean at 8:1 row ratio	T_6

3.6. LAYOUT PLAN

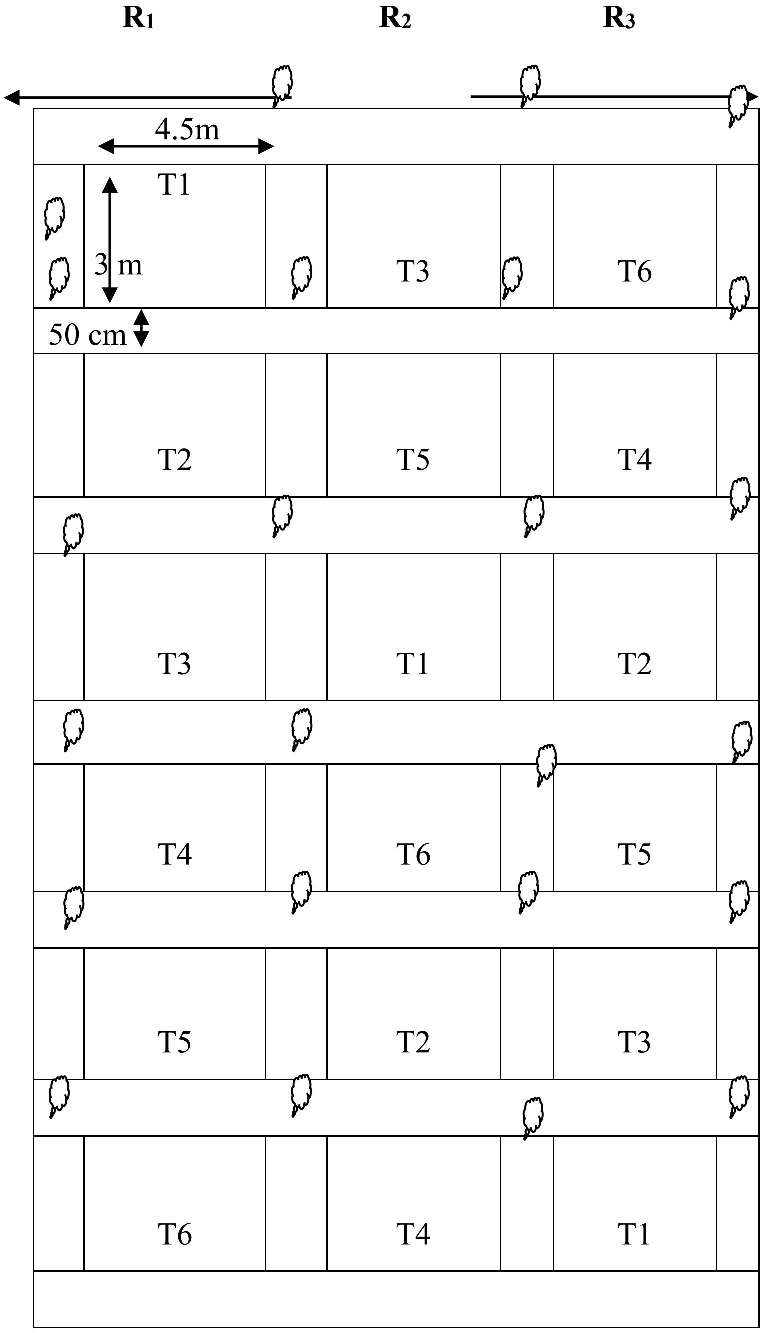


FIGURE 3.2 : LAYOUT PLAN OF EXPERIMENTAL FIELD

Gross plot = 4.5 × 3 m = 13.5 m^2

Width of bund = 50 cm

Net plot size = 3.5 × 2 m = 7 m^2

Spacing = 40 × 10 cm

3.7 Details of Layout

Experimental design	:	RBD (Randomized Block Design)
Season	:	*Kharif*, 2011
Crop	:	Pearl millet and cluster bean
Test intercrops	:	Pearl millet + cluster bean
Total Treatment	:	06
No. of replication	:	03
Total no. of plots	:	18
Net plot size	:	4.5 x 3 m = 13.5 m^2
Spacing		
Row to row	:	40 cm
Plant to plant	:	10 cm
Plot border	:	50 cm
Field border	:	1 m

3.6 SALIENT FEATURES OF EXPERIMENTAL CROPS

Pearl millet and cluster bean crops were chosen for conducting the experiment under agro- horti system for their performance of such crops with sole and intercrops with different row spacing ratio.

3.6.1 CULTIVARS

(a) Pearlmillet:

The pearl millet variety B-855 (Hybrid Bajara) is a variety of Zone B which matures in 80-90 days, drought resistant, tall (220cm.), thick semi-compact to compact cylindrical ear head, yellow anthers, obviate, grey grains, dual purpose variety having yield potential of 18-20 quintals ha^{-1} bred from 59 plants of NELC C4 selected at Patancheru.

(b) Cluster bean**:** The cluster bean variety Muskan (guar) a recommended variety for cultivation in summer and *Kharif* both seasons was grown. Compact and short in growth habit with average plant height 100- 120 cm. This variety matures in 80-90 days. Seeds are bold (35 gram per 1000 grain) and of shining green in colour. The variety has almost uniform maturity and may be harvested only one time. Yield potential is 10- 12 quintal per hectare.

3.7 DETAILS OF CROP RAISING

The details of cultural operations done starting from field preparation to harvesting of the crops are given in Table 3. 8.

3.7.1 Field preparation

After rains, the experimental field was prepared by two cross harrowing followed by planking. The experiment was laid as per plan of layout and design.

3.7.2 Seed rate, seed treatment and sowing

The seed of crops were sown @ 5 kg ha^{-1} of pearl millet and 20 kg ha^{-1} of cluster bean in lines spaced as per treatments in sole cropping. The seeds of pearl millet and cluster bean were seed treatment with thiram 3 gram / kg seeds of pearl millet and bavestin 3 g kg^{1} seeds of cluster bean, respectively for fungal diseases control. In intercropping treatments row to row distance maintained was 45 and 10 cm and sowing was done by "*Kera*" method in open furrow on 10.08.2011.

Table 3.8: Calendar of fields operation:

S.No.	Operation	Date	Remark
1.	Field preparation	9.08.2011	One ploughing with disc harrow and two with cultivator followed by planking.
2.	Layout	10.08.2011	Demarcation of plot.
3.	Sowing	10.08.2011	Seed was paced by hand at about 4 cm deep using.
4.	Fertilizer application	10.08.2011	Half dose of nitrogen and full dose of phosphorus (K_2O_5), potassium (K_2O) are applied as a basal at sowing as time.
6.	Thinning and gap filling	28.09.2011	To maintain uniform plant population.
7.	Weeding and hoeing	I 14.09.2011 II 10.09.2011	To remove the germinating weed and loosen the surface of soil.
8.	Urea top dressing	02.10.2011	Remaining half dose of nitrogen top dressed.
9.	Harvesting	7.10.2011	By sickle
10.	Threshing	23.10.2011	By beating

3.7.2 Fertilizer application

The 80 kg N ha^{-1} nitrogen was applied through urea & DAP, 40 kg P_2O_5 ha^{-1} phosphorus through DAP and 40 kg K_2O ha^{-1} Potassium through MOP prior to sowing.

3.7.3 Thinning and gap filling

Extra plants were thinning and gap filling was done manually at 18 days after sowing maintaining the plant to plant spacing of 10 cm.

3.7.4 Hoeing and weeding

Hoeing and weeding was done manually at 30 DAS with the help of hoe locally knows as “Kasola or Kasia” and the field was kept practically weed free.

3.7.5 Harvesting

Crops were harvested at complete maturity as judged by visual observations. The border rows were harvested first and kept aside. Thereafter, the net plots were harvested by hand picking of the pods when nearly 80 percent pods were matured and harvested crop was left in the field for drying for a period of 3-4 days. To assess the biological seed and straw yields, harvesting was done from each plot by sickles, tied in bundles and tagged. These tagged bundles were left for sun drying in the plots. After complete drying, the bundles were weighed using physical balance and weight of each bundle was recorded in kg and converted to kg ha^{-1} as biological yield.

3.7.7 Threshing and winnowing

Threshing was done manually by beating and trampling the ears and pods of each plot separately and grains were collected in numbered bags. After winnowing, cleaned seeds were weighed to record grain yield. The straw yield was computed by subtracting the seed yield from biological yield.

3.8 Experimental observation

Observation on guava, pearl millet and cluster bean were recorded taking all the precaution to eliminate the sampling error.

3.9 Biometric Observations

Five plants from each plot were randomly selected and tagged for recording the biometric observations at different stages of growth. The observations on growth attributes were recorded at an interval of 25 days *i.e.* 25^{th}, $50^{th,}$ 75^{th} days after sowing (DAS) and at harvest.

Yield attributes and yield were studied before and after harvesting as per investigation required. The methodology adopted for recording each of the aforesaid observations is given as follows.

3.9.1 TREATMENT EVOLUTION OF PEARLMILLET

3.9.1 Growth attributes:

Growth attributes *viz*, plant height, number of leaves, number of tillers, were recorded at 25 days intervals starting from 25 days after sowing to harvesting of crop and for this, three plant in each plot were selected randomly and tagged with wax coated labels.

3.9.1.1 Plant height:

Height of randomly selected and marked plants from each plot was measured from base of the plants up to growing tip of main stem. The average plant height was calculated by taking the mean of observation of five plants and expressed in cm.

3.9.1.2 Plant leaves:

The number of green leaves per plant of pearl millet was counted at different stages of the crop growth from the selected tagged plants per plot and mean of observation of five plants was computed.

3.9.1.3 Number of tillers per plant

Total number of tillers which include the main shoot and effective tillers (ear bearing) were counted periodically of three plants

3.9.1.4 Dry weight of plant:

Dry weight of the tagged plants in each plot was taken with the help of spring balance after drying plants.

3.9.2 YIELD AND YIELD ATTRIBUTES:

One meter square which were used for recording observations on growth components were harvested separately and were subjected to the following studies.

3.9.2.1 Ear perimeter:

The perimeter was measured with the help of yarn and meter scale in the base middle of ears.

3.9.2.1.1 Number of grain ear^{-1}

The number of grain was measured by hand method

3.9.2.1.2 Girth of the ears:

The diameter was measured with the help of *Vernier caliper* in the base middle of ears.

3.9.2.1.3 Length of ears:

Above selected ear were measured in cm from the basis of ear to the top of the last spikelets.

3.9.2.1.4. Yield (m^{-2}), Yield per ear and Ear weight:

The yield (m^{-2}), per ar was taken after harvesting of crop with the help of balance.

3.9.2.2 Grain yield:

The threshing was done by manual beating and then grain yield of each plot was weighted. The grain produce per plot was calculated in kg^{-1} hectare.

3.9.2.3 Straw yield:

The straw yield was worked out after deducting the grain yield form the produce of the each plot, it was then calculated in kg^{-1} hectare.

3.9.2.4 Biological yield

Biological yield per plot was calculated by weighing the total biomass of individual plot before threshing. It was worked out as biological yield kg-^{1} hectare.

3.9.2.5 Test weight of seed (1000-grain weight):

For this samples of grain were taken farm produce of each plot 1000 grain were counted and weighted in gram.

3.9.2 .6 Harvest index:

The harvest index was calculated by dividing the economic yield by the biological yield and multiplying by 100. It is express in per cent.

$$\text{Harvest index}(\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.9.3 Evaluation of cluster bean

The methodology used for evaluating the different treatments in terms of growth and yield of crop have been given here under:

3.9.3.1 Growth attributes

For evaluating growth attributes, five plants were randomly selected in each plot from the sampling rows and tagged permanently.

3.9.3.2 Plant height

The height of five permanently tagged plants from each plot was measured from the base to the apex of the main shoot with the help of meter scale at crop maturity and the average of the five plants was recorded as mean plant height (cm).

3.9.3.3 Number of branches plant^{-1}

The branches of five randomly selected plants were counted average number of branches plant^{-1} was worked out and recorded as number of branches plant^{-1}.

3.9.3.4 Dry matter accumulation/plant (g)

For recording dry matter accumulation, 5 plants from each plot were cut from the ground level of border rows. Sampled plants were sun dried first then dried in an oven for 24 hours to get constant dry weight. Thereafter, the average dry weight was recorded in g plant.

3.9.4 Yield and yield attributes

One meter square which were used for recording observations on growth components were harvested separately and were subjected to the following studies.

3.9.4.1 Number of cluster plant^{-1}

The cluster of five randomly selected plants were counted and average number of cluster plant^{-1} was worked out and recorded as number of cluster plant^{-1}.

3.9.4.1.1 Number of pods plant^{-1}

The pods of five randomly selected plants were counted and average number of pod plant^{-1} was worked out and recorded as number of pod plant^{-1}.

3.9.4.1. Number of grain pod^{-1}

The seeds of twenty randomly pods of selected plants were counted and average number of grain pod^{-1} was worked out and recorded as number of grain pod^{-1}.

3.9.4.2 Grain Yield

The seed yield of each net plot was recorded after cleaning the threshed produce and was converted as kg ha^{-1}.

3.9.4.3 Straw yield

The Straw yield (kg plot^{-1}) was obtained by subtracting the seed yield from biological yield recorded earlier and then convert in terms of kg ha^{-1}.

3.9.4.4 Biological yield

The harvested material from net area of each plot was thoroughly sun dried. After drying, the produce of individual plot area was weighed with the help of a spring balance and weight recorded in kg plot^{-1}. Later, biological yield plot^{-1} was converted in terms of kg ha^{-1}.

3.9.4.5 Harvest index

The harvest index was worked out by dividing the seed yield (economic yield) by seed + straw yield (biological yield) obtained from net plot area and multiplies by 100 to express it in per cent (Singh and Stoskohpf, 1971)

$$\text{Harvest index}(\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.9.4.6 Test weight (1000- seed weight)

A small seed sample was taken from the produce of each of the net plot harvested and 1000-seeds were counted and weighed in grams.

3.9.5 Guava

It is erect, with a rounded or spreading crown and trunk 22-30 cm thick. Height ranges from 2.45 to 2.66 meter. The ill-smelling leaves are deciduous, alternate, oblong or narrow-lanceolate, 4 to 8 in (10-20 cm) long, 3/4 to 2 in (2 5 cm) wide, with conspicuous veins. Flowers, in drooping clusters, are fragrant, slender, with 3 outer fleshy, narrow petals 3/4 to 1 1/4 in (2 3 cm) long; light-green externally and pale-yellow with a dark-red or purple spot on the inside at the base. The flowers never fully open. The guava does best in low-lying, deep, rich soil with ample moisture and good drainage.

3.9.5.1 Growth parameters of guava

The following growth parameters of guava, situated at border of the plot, were recorded at the scheduled dates.

3.9.5.1.1 Height

The height of custard apple was measured from base of the plants up to growing tip of main stem. The plant height was measured and expressed in feet.

Height (meter)		
At sowing	40 DAS	At harvest
2.45	2.55	2.66

3.9.5 .1.2 Canopy

The canopy area of guava was recorded with the help of meter tape and it was recorded from the highest canopy diameter in feet.

Canopy diameter(feet)		
At sowing	**40 DAS**	**At harvest**
E.W.- 3.23	E.S.- 3.31	E.W- 3.40
N.S.- 3.33	N.S.- 3.51	N.S.- 3.56

3.9.5.1.3 Stem girth

The stem girth of custard apple was recorded from base of the plants in inches which was situated at the plot of the crops.

Stem girth (cm)		
At sowing	**40 DAS**	**At harvest**
24.31	25.31	24.31

3.9.5.1.4 Shading

The shading area of the custard apple was recorded with the help of meter tape and measured as width and length in feet.

Shading area (Meter)					
At sowing		**40 DAS**		**At harvest**	
Length	**Width**	**Length**	**Width**	**Length**	**Width**
2.15	3.43	2.18	3.51	2.23	3.58

3.9.5.1.5 Yield (kg^{-1} ha)

The guava has the advantage of cropping in late winter and spring when the preferred members of the genus are not in season. It is picked when it has lost all green colour and ripens without splitting so that it is readily sold in local markets. If picked green, it will not colour well and will be of inferior quality. The tree is naturally a fairly heavy bearer. The average yield was noticed 730 kg^{-1} ha.

3.9.6 Quality attributes

3.9.6.1 Nitrogen concentration and its uptake

The seed and stalk / straw samples were analysed separately for pearl millet and Cluster bean for nitrogen concentration as per standard colorimetric method

(Snell and Snell, 1949). The uptake of nitrogen by crop was calculated by following formula:

$$\text{N uptake (kg}^{-1}\text{ ha)} = \frac{\left(\begin{array}{c}\text{Per cent N in seed}\\ \text{Seed yield (kg ha}^{-1}\text{)}\end{array}\right) \text{x} + \left(\begin{array}{c}\text{Per cent N in stalk/straw x}\\ \text{Stalk/straw yield (kg ha}^{-1}\text{)}\end{array}\right)}{100}$$

3.9.6.1 Protein content in seed

Seed protein content of Pearl millet & Cluster bean crop was calculated by multiplying the per cent N content in seed with the factor of 6.25 (A.O.A.C., 1960).

3.9.7 Indices

3.9.7.1 Pearlmillet equivalent yield

Seed yield of Cluster bean was calculated in terms of Pearl millet for all intercropping treatments. On the basis of their market price and then analyzed statistically as equivalent grain yield of Pearl millet treatment using the following formula:

$$\text{Pearl millet grain equivalent yield (kg ha}^{-1}\text{)} = \frac{\text{Yield of intercrop (kg ha}^{-1}\text{)} \ \text{X} \ \text{Price of intercrop (Rs. kg}^{-1}\text{)}}{\text{Price of pearl millet (Rs. kg}^{-1}\text{)}} + \text{Pearl millet grain yield (kg ha}^{-1}\text{)}$$

3.9.7.2 Land equivalent ratio

It denotes the relative land area under sole crop required to produce the same yield as obtained under a mixed or an intercropping system at the same management level. It is calculated as sum total of the ratios of yield of each component crop in an intercropping system to its corresponding yield when grown as a sole crop thus:

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

Yab= is the yield of crop ‘a’ in association with crop ‘b’

Yba=is the yield of crop ‘b’ in association with crop ‘a’

Yaa=is the pure stand yield of crop 'a'

Ybb = is the pure stand yield of crop 'b'

3.9.8 Economic analysis

3.9.8.1 Net returns (Rs. ha^{-1})

To find out the more profitable treatment, economics of different treatments were worked out in terms of net returns (Rs. ha^{-1}) on the basis of the prevailing market rate so that the most remunerative treatment could be recommended.

Net return (Rs. ha^{-1}) = Gross return (Rs. ha^{-1}) - Cost of cultivation (Rs. ha^{-1})

3.9.8.2 Benefit: Cost (B:C) ratio

Benefit cost ratio for each treatment was calculated to ascertain economic viability

$$\text{B: C ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

3.9.8.3. Statistical Analysis:

The data collected during the experimental period and after harvest of the experiment was statistically analysis employing the following statistical techniques.

3.9.8.3.1. Analysis of variance:

The details of different sources of variance of variation and breakup of the degree of freedom have been given in the following table of analysis variance.

Table 3.9: Analysis of variance (ANOVA)

Source of variance	D. F.	S.S.	M.S.S.	F Value calculated	Value table	
					5%	1%
RSS	2					
BSS	1					
Trss	3					
Trss x Bss	3					
Eror	14					
Total	23					

3.9.8.3.2. Standard errors critical difference:

In order to compare the different level of a particular factor and the different treatment combinations critical differences at 5% level of significance were calculated with the help of formula which are used in the analysis of factorial randomized block design. Any difference between the two mean equal to or greater than the critical difference was declared as significant.

S.E. for difference between two treatment means:

$$\text{S.E.} \pm \text{diff. for treatment} = \frac{\sqrt{2VE}}{r} = \frac{\sqrt{2VE}}{3}$$

Critical difference = (S.E.) diff. x $t_{5\%}$ (12)

Chapter-IV

EXPERIMENTAL FINDINGS

The present investigation entitled **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + Cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of Vindyan region"** conducted during *khakis* season of 2011 at Agricultural research farm of RGSC, BHU, Barkachha, are presented and described in this chapter. For treatment evaluation, the data were subjected to statistical analysis using various criteria and their significance tested.

4.1 Growth attributes of Pearl millet

4.1.1 Plant Height

Data relating to plant height have been presented in Table 4.1 and depicted in fig. 4.1. Data revealed that plant height of pearl millet was influenced significantly due to the different row ratio intercropping system at 25, 50, 75 DAS and at harvest stage of crop. Intercropping ratio had significantly effect on plant height over pearl millet sole planting at 25, 50, 75 DAS and at harvest.

Table -4.1: Effect of planting pattern on plant height of pearl millet.

Treatment	Plant height (cm)			
	25 DAS	50 DAS	75 DAS	At Harvest
T_1 –Pearl millet sole	52.43	116.89	180.64	188.82
T_2 –Cluster bean sole	-	-	-	-
T_3 –Pearl millet: cluster bean (2:1)	60.12	120.55	189.73	198.04
T_4 –Pearl millet: cluster bean (4:1)	64.15	125.53	193.14	201.33
T_5 –Pearl millet: cluster bean (6:1)	66.72	126.45	197.83	205.23
T_6 –Pearl millet: cluster bean (8:1)	57.20	119.08	186.24	192.45
SEm±	1.45	1.77	2.13	1.80
C.D. (P=0.05)	4.24	5.18	6.25	5.27

The maximum plant height 66.72, 125.45, 197.83 and 205.23 cm at 25, 50, 75 DAS and at harvest stage was observed under pearl millet : cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean (T_4) 4:1 was at par with (T_5) treatment and significantly taller plants over (T_1) and (T_6) at all the growth stage of crop. A gradual decrease in plant height were observed under pearl millet: cluster bean (T_4) 4:1, pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum plant height of 52.43, 119.08, 180.08 and 192.45 cm were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

4.1.2 Number of leaves:

Data relating to the no. of leaves as affected by different intercropping are presented in Table 4.2 and fig 4.2. Different intercropping system cause the significant differences on no. of leaves at 25 and 75 DAS and non significant differences were observed at 50 DAS and at harvest stage.

The maximum no. of leaves 10.40, 16.58, 26.44 and 24.61 at 25, 50, 75 DAS and harvest stage were recorded in pearl millet: cluster bean 6:1 (T_5) followed by pearl millet: cluster bean 4:1 (T4). Minimum no. of leaves 7.41, 13.48, 21.84 and 22.04 were observed in pearl millet sole (T1).

Table -4.2: Effect of planting pattern on number of leaves pearl millet

Treatment	No. of leaves			
	25 DAS	50 DAS	75 DAS	At Harvest
T_1 –Pearl millet sole	7.41	13.48	21.84	22.04
T_2 –Cluster bean sole	-	-	-	-
T_3 –Pearl millet: cluster bean (2:1)	8.69	13.68	23.64	23.98
T_4 –Pearl millet: cluster bean (4:1)	9.48	14.87	25.02	25.22
T_5 –Pearl millet: cluster bean (6:1)	10.40	16.58	26.44	26.64
T_6 –Pearl millet: cluster bean (8:1)	7.82	13.14	22.76	22.96
SEm$\pm$	0.32	1.02	1.06	1.05
C.D. (P=0.05)	0.93	NS	3.09	3.07

4.1.3 Number of tillers plant^{-1}

Data relating to plant tiller have been presented in Table 4.3 and depicted in fig. 4.3. Data revealed that plant tiller of pearl millet was influenced significantly due to the different row ratio intercropping system at 25, 50, 75 DAS and at harvest stage of crop. Intercropping ratio had significantly effect on plant tiller over pearl millet sole planting. At 25, 50, 75 DAS and at harvest, the planting pearl millet: cluster bean ratios are 6:1, 4:1, 2:1, 8:1 intercropping ratios were significantly plant tiller over (T_1) pearl millet sole. The maximum plant tiller 2.03, 2.70, 3.29 and 3.37 at 25, 50, 75 DAS and at harvest stage was observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly tiller plants over T_1 and T_6 at all the growth stage of crop . A gradual decrease in plant tiller were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum plant tiller of 1.80, 2.09, 2.98 and 2.93 were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

Table -4.3: Effect of planting pattern on number of tillers pearl millet

Treatment	No. of tiller			
	25 DAS	50 DAS	75 DAS	At Harvest
T_1 –Pearl millet sole	1.80	2.09	2..98	2.93
T_2 –Cluster bean sole	-	-	-	-
T_3 ⁻Pearl millet: cluster bean (2:1)	1.88	2.27	3.09	3.18
T_4 –Pearl millet: cluster bean (4:1)	1.95	2.61	3.21	3.28
T_5 –Pearl millet: cluster bean (6:1)	2.03	2.70	3.29	3.37
T_6 –Pearl millet: cluster bean (8:1)	1.86	2.15	3.02	3.09
SEm$\pm$	0.04	0.04	0.03	0.04
C.D. (P=0.05)	0.13	0.12	0.10	0.11

4.1.4 Dry matter accumulation (g plant^{-1})

Data relating to dry matter accumulation plant^{-1} have been presented in Table 4.4 and depicted in fig. 4.4.Data revealed that dry matter accumulation plant^{-1} of pearl millet was influenced significantly due to the different row ratio intercropping system at 25, 50, 75 DAS and at harvest stage of crop. Intercropping ratio had significantly effect on dry matter accumulation plant^{-1} over pearl millet sole planting. At 25, 50, 75 DAS and at harvest, the planting pearl millet: cluster bean ratios are 6:1, 4:1, 2:1, 8:1 intercropping ratios were significantly dry matter accumulation plant^{-1} over (T_1) pearl millet sole.

The maximum dry matter accumulation plant^{-1} 7.48, 57.96, 115.40 and 134.86 at 25, 50, 75 DAS and at harvest stage was observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly dry matter accumulation plant^{-1} over T_1 and T_6 at all the growth stage of crop. A gradual decrease in dry matter accumulation plant^{-1} were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum dry matter accumulation plant^{-1} of 6.31, 47.65, 98.22and 112.81 were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

Table -4.4: Effect of planting pattern on dry weight (g) of pear millet

Treatment	Dry weight plant^{-1}			
	25 DAS	**50 DAS**	**75 DAS**	**At Harvest**
T_1 –Pearl millet sole	6.31	47.65	98.22	112.81
T_2 –Cluster bean sole	-	-	-	-
T_3 –Pearl millet: cluster bean (2:1)	6.82	50.92	105.35	127.26
T_4 –Pearl millet: cluster bean (4:1)	7.34	54.33	110.02	131.08
T_5 –Pearl millet: cluster bean (6:1)	7.48	57.96	115.40	134.86
T_6 –Pearl millet: cluster bean (8:1)	6.59	49.59	101.92	121.32
SEm$\pm$	0.13	1.42	2.37	2.16
C.D. (P=0.05)	0.38	4.16	6.92	6.31

4.2 Yield and yield attributes:

The data related to result of yield attributes of pearl millet as ear perimeter, grains and straw yield, test weight and biological yield have been summarized in Table 4.5, and 4.6 and Fig. 4.5 and 4.6.

4.2.1 Yield attributing characters

4.2.1.1 No. of grain ear^{-1}

Data relating to No. of grains ear^{-1} as affected by non significant different intercropping row ratio. The maximum No. of grains ear^{-1} was observed in pearl millet: cluster bean 6:1 (T_5) 1416.75 followed by pearl millet: cluster bean 4:1 (T_4) 1391.36 and minimum no. of grain ear^{-1} were observed in pearl millet sole (T_1) 1275.61.

4.2.1.2 Test weight (g)

Data relating to Test weight as affected by non significant different intercropping row ratio. The maximum Test weight was observed in pearl millet: cluster bean 6:1 (T_5) 9.89 (g) followed by pearl millet: cluster bean 4:1 (T_4) 9.52 (g) and Minimum Test weight were observed in pearl millet sole (T_1) 8.35 (g).

4.2.1.3 Ear girth (cm)

Data revealed that ear girth of pearl millet was influenced significantly due to different row ratio intercropping system. Intercropping ratio had significantly effect on ear girth over pearl millet sole planting, the planting pearl millet: cluster bean ratios are 6:1, 4:1, 2:1, 8:1 intercropping ratios were significantly ear girth over (T_1) pearl millet sole. The maximum ear girth was 10.55 cm observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly ear girth over T_1 and T_6 at all ear girth (cm) of crop . A gradual decrease in ear girth (cm) were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum ear girth of 10 cm was observed under (T_1) sole pearl millet.

4.2.1.4 Ear length (cm)

Data relating to ear length (cm) as affected by non significant different intercropping row ratio. The maximum ear length (cm) was observed in pearl millet: cluster bean 6:1 (T_5) 23.82 followed by pearl millet: cluster bean 4:1 (T_4) 22.03 and Minimum Test weight were observed in pearl millet sole (T_1) 20.57

4.2.1.5 Ear weight (g)

Data revealed that ear weight (g) of pearl millet was influenced significantly due to different row ratio intercropping system. Intercropping ratio had significantly effect on ear weight (g) over pearl millet sole planting., the planting pearl millet: cluster bean ratios are 6:1, 4:1, 2:1, 8:1 intercropping ratios were significantly ear weight (g) over (T_1) pearl millet sole. The maximum ear weight (g) was 24.75 observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly ear weight (g) over T_1 and T_6 at all ear weight (g) of crop. A gradual decrease in ear weight (g) were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively. The minimum ear weight (g) of 10 (cm) was observed under (T_1) sole cropping at 25, 50, 75 DAS and harvest.

Table -4.5: Effect of planting pattern on yield attributes of pearl millet

Treatment	No. of Grains ear^{-1}	Test wt. (g)	Ear girth (cm)	Ear length cm	Ear wt. (g)
T_1 -Pearl millet sole	1275.61	8.35	9.98	20.57	21.28
T_2 -Cluster bean sole	-	-	-	-	-
T_5 -Pearl millet: cluster bean (2:1)	1347.32	9.25	10.27	21.77	22.11
T_5 -Pearl millet: cluster bean (4:1)	1391.36	9.52	10.46	22.03	23.67
T_5- Pearl millet: cluster bean (6:1)	1416.75	9.89	10.55	23.82	24.75
T_6 -Pearl millet: cluster bean (8:1)	1315.77	8.91	10.18	21.16	21.67
SEm$\pm$	64.70	0.39	0.09	1.11	0.82
C.D. (P=0.05)	NS	NS	0.26	NS	2.39

4.2.1.6 Grain yield

Intercropping patterns brought about perceptible improvement in grain yield of Pearl millet. The data on Grain yield have been summarized in Table 4.6 and fig. 4.6

The maximum grain yield 1554.53 kg ha^{-1} recorded under (T_1) pearl millet sole over rest of other treatments. All the treatments combination (T_3), (T_4), (T_5) and (T_6) inter cropping ratios were significantly produced lower in grain yield from the sole crop. The minimum grain yield 1120.24 kg ha^{-1} was observed under pearl millet: cluster bean 6:1 (T_3) intercropping, system at harvest stage.

4.2.1.7 Straw yield

The data pertaining to straw yield of pearl millet have been presented in Table 4.8 and depicted in fig. 4.8. Intercropping patterns practices brought about perceptible improvement in straw yield of pearl millet. The maximum straw yield 5104.11 kg ha^{-1} recorded under pearl millet sole (T_1) which was significantly superior over rest of the treatments as compared to pearl millet: cluster bean 2:1 (T_3), pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 6:1 (T_3) respectively in intercropping. The minimum straw yield 6167.94 kg ha^{-1} was observed under pearl millet: cluster bean 8:1 (T_6) intercropping treatment at harvest stage .

4.2.1.8 Biological yield

The data pertaining to biological yield of pearl millet have been presented in Table 4.6 and depicted in fig. 4.6. Intercropping patterns practices brought about perceptible improvement in biological yield of Pearl millet. The maximum biological yield 6658.64 kg ha^{-1} recorded under pearl millet sole (T_1) treatment which was significantly superior over rest of other row ratios treatments. The maximum biological yield 6658.64 kg ha^{-1} recorded under pearl millet sole (T_1) was superior over rest of the treatments as compared to pearl millet: cluster bean 2:1 (T_3), pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 6:1 (T_3) respectively in intercropping. The minimum straw yield 6167.94 kg ha^{-1} was observed under pearl millet: cluster bean 8:1 (T_6) intercropping treatment at harvest stage.

4.2.1.9 Harvest index

The data on harvest index as influenced by different treatments have been presented in Table 4.6 and depicted in fig. 4.6.The data pertaining to harvest index revealed that among intercropping treatment the highest value of harvest index was recorded under pearl millet: cluster bean 4:1 (T_4) 23.47 percent which was non significantly superior over rest of all other row ratios treatments. All the treatments combination (T_1), (T_3), (T_4) and (T_6) intercropping ratios were found significant effect on harvest index. The highest value of harvest index was recorded under pearl millet: cluster bean 4:1 (T_4), 23.47 per cent was superior and followed by the pearl millet: cluster bean 2:1 (T_3), 23.42 per cent, pearl millet: cluster bean 6:1 (T_5) 23.36, pearl millet: cluster bean 8:1 (T_6), and pearl millet sole (T_1) 23.35%, respectively in intercropping treatment. The minimum harvest index 23.35 % was recorded in pearl millet sole (T_1) 23.35%.

Table -4.6: Effect of planting pattern on grain, straw, biological yields and harvest index of pearl millet

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1 -Pearl millet sole	1554.53	5104.11	6658.64	23.35
T_2 -Cluster bean sole	-	-	-	-
T_3 -Pearl millet: cluster bean (2:1)	1120.24	3663.20	4783.44	23.42
T_4 -Pearl millet: cluster bean (4:1)	1302.19	4245.17	5547.36	23.47
T_5 -Pearl millet: cluster bean (6:1)	1505.40	4937.70	6443.10	23.36
T_6 -Pearl millet: cluster bean (8:1)	1441.11	4726.83	6167.94	23.36
SEm$\pm$	2.53	15.82	17.85	0.05
C.D. (P=0.05)	7.58	46.30	52.22	NS

4.3 Evaluation of cluster bean

4.3.1. Growth attributes of cluster bean

4.3.1.1 Plant Height

Data relating to plant height have been presented in Table 4.7 and depicted in fig. 4.7

Data revealed that plant height of cluster bean was influenced significantly due to the different row ratio intercropping system at 25, 50, 75 DAS and at harvest stage of crop. Intercropping ratio had significantly effect on plant height over cluster bean sole planting at all stages of crop growth.

The maximum plant height 27.38, 85.49, 114.90 and 118.73 cm at 25, 50, 75 DAS and at harvest stage was observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly taller plants over T_1 and T_6 at all the growth stage of crop . A gradual decrease in plant height were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum plant height of 21.34, 66.58, 101.34 and 106.62 cm were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

Table -4.7: Effect of planting pattern on plant height of cluster bean

Treatment	Plant height (cm)			
	25 DAS	50 DAS	75 DAS	At Harvest
T_1 -Pearl millet sole	-	-	-	-
T_2 - Cluster bean sole	21.34	66.58	101.34	106.62
T3 -Pearl millet: cluster bean (2:1)	23.67	81.73	106.63	114.50
T4 -Pearl millet: cluster bean (4:1)	25.55	84.62	112.21	115.73
T_5 - Pearl millet: cluster bean (6:1)	27.38	85.49	114.90	118.73
T_6 -Pearl millet: cluster bean (8:1)	23.60	77.26	104.02	111.73
SEm±	0.82	0.83	0.94	1.04
C.D. (P=0.05)	2.41	2.44	2.76	3.06

4.3.1.2 Number of branches plant^{-1}

Data relating to no. of branches plant^{-1} have been presented in Table 4.8 and depicted in fig. 4.8. Data revealed that no. of branches plant^{-1} of cluster bean was influenced significantly due to the different row ratio intercropping system. Intercropping ratio had significantly effect on no. of branches plant^{-1} over cluster bean sole planting at 25, 50, 75 DAS and at harvest.

The maximum no. of branches plant^{-1} 1.74, 3.72, 4.61 and 4.62 at 25, 50, 75 DAS and at harvest stage was observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly no. of branches plant^{-1} over T_1 and T_6 at all the growth stage of crop. A gradual decrease in no. of branches plant^{-1} were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum no. of branches plant^{-1} of 1.11, 2.33, 2.67 and 2.69 were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

Table -4.8: Effect of planting pattern on number of branches of cluster bean

Treatment	No. of branch			
	25 DAS	50 DAS	75 DAS	At Harvest
T1 -Pearl millet sole	-	-	-	-
T_2- Cluster bean sole	1.11	2.33	2.67	2.66
T_3 -Pearl millet: cluster bean (2:1)	1.39	2.77	4.11	4.23
T_4 -Pearl millet: cluster bean (4:1)	1.64	3.57	4.51	4.38
T_5 -Pearl millet: cluster bean (6:1)	1.74	3.72	4.61	4.62
T_6 -Pearl millet: cluster bean (8:1)	1.27	2.51	3.29	3.31
SEm$\pm$	0.03	0.06	0.10	0.13
C.D. (P=0.05)	0.10	0.17	0.29	0.37

4.3.1.3 Dry matter accumulation (g plant^{-1}):

Data relating to dry weight of plant^{-1} have been presented in Table 4.9and depicted in fig. 4.9

Data revealed that to dry weight of plant^{-1} of cluster bean was influenced significantly due to the different row ratio intercropping system at 25, 50, 75 DAS and at harvest stage of crop. Intercropping ratio had significantly effect on dry weight of plant^{-1} over cluster bean sole planting. At 25, 50, 75 DAS and at harvest, the planting pearl millet: cluster bean ratios are 6:1, 4:1, 2:1, 8:1 intercropping ratios were significantly dry weight of plant^{-1} over (T_1) pearl millet sole.

The maximum dry weight of plant^{-1} 2.27, 11.59, 24.89 and 27.83 at 25, 50, 75 DAS and at harvest stage was observed under pearl millet: cluster bean 6:1 (T_5) intercropping treatment and pearl millet: cluster bean 4:1 (T_4) was at par with (T_5) treatment and significantly dry weight of plant^{-1} over T_1 and T_6 at all the growth stage of crop . A gradual decrease in dry weight of plant^{-1} were observed under pearl millet: cluster bean 4:1 (T_4), pearl millet: cluster bean 2:1 (T_3) and pearl millet: cluster bean 8:1 (T_6) respectively intercropping. The minimum dry weight of plant^{-1} of 1.70, 10.54, 22.55 and 25.61 were observed under (T_1) sole cropping method at 25, 50, 75 DAS and harvest.

Table -4.9: Effect of planting pattern on dry weight of cluster bean

Treatment	Dry weight (g)			
	25 DAS	50 DAS	75 DAS	At Harvest
T_1 -Pearl millet sole	-	-	-	-
T_2 -Cluster bean sole	1.70	10.54	22.55	25.61
T_3 -Pearl millet: cluster bean (2:1)	1.92	10.88	22.83	25.82
T_4 -Pearl millet: cluster bean (4:1)	2.10	11.46	23.80	26.92
T_5-Pearl millet: cluster bean (6:1)	2.27	11.59	24.89	27.83
T_6 -Pearl millet: cluster bean (8:1)	1.79	10.70	22.69	25.75
SEm$\pm$	0.11	0.18	0.40	0.34
C.D. (P=0.05)	0.31	0.54	1.16	0.98

4.3.2. Yield attributes and Yield (kg ha^{-1}):

The data related to result of yield attributes of cluster bean as no clusters $plant^{-1}$, no. pod $plant^{-1}$, no. of grain $pod^{-1,}$ test weight (g) and seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), and biological yield (kg ha^{-1}) and harvest index (%) have been summarized in Table 4.10 and Fig. 4.10

4.3.2.1 No. of clusters $plant^{-1}$

Data related to no. of clusters $plant^{-1}$ was infused significantly different intercropping row ratio. The maximum no. of clusters $plant^{-1}$ was observed in pearl millet: cluster bean 6:1 (T_5) 8.94 followed by (T_4) 8.84 and significantly superior over (T_1). The minimum no of clusters $plant^{-1}$ was recorded in sole 7.03.

4.3.2.2 No. of pod $plant^{-1}$

Data related to no. of pod $plant^{-1}$ was infused significantly different intercropping row ratio. The maximum no. of pod plant¯1 was observed in pearl millet: cluster bean 6:1 (T_5) 34.05 followed by (T_4) 33.80 and significantly superior over (T_1). The minimum no. of clusters $plant^{-1}$ was recorded in sole 31.18.

4.3.2.3 No. of grain pod^{-1}

Data related to no. of grain pod^{-1} was infused significantly different intercropping row ratio. The maximum no. of grain $plant^{-1}$ was observed in pearl millet: cluster bean 6:1 (T_5) 7.69 followed by (T_4) 7.59 and significantly superior over (T_1). The minimum no of grain pod^{-1} was recorded in sole 6.99.

4.3.2.4 Test weight (g)

Data relating to Test weight as affected by non significant different intercropping row ratio. The maximum Test weight was observed in pearl millet: cluster bean 6:1 (T_5) 31.97 (g) followed by pearl millet: cluster bean 4:1 (T_4) 8.84 (g) and minimum Test weight were observed in pearl millet sole (T_1) 7.03 (g).

Table -4.10: Effect planting pattern on yield attributes of cluster bean

Treatment	Clusters plant^{-1} (no.)	Pods plant^{-1} (no.)	Grains pod^{-1} (no.)	Test weight (g)
T1 -Pearl millet sole	-	-	-	-
T_2 - Cluster bean sole	7.03	31.18	6.99	31.09
T3-Pearl millet: cluster bean (2:1)	8.73	33.49	7.50	31.79
T_4 -Pearl millet: cluster bean (4:1)	8.84	33.80	7.59	31.93
T_5 -Pearl millet: cluster bean (6:1)	8.94	34.05	7.69	31.97
T_6 -Pearl millet: cluster bean (8:1)	8.57	33.24	7.11	31.55
SEm$\pm$	0.51	0.73	0.18	0.69
C.D. (P=0.05)	1.49	2.73	0.52	NS

4.3.2.5 Straw yield (kg ha.$^{-1}$)

Data relating to straw yield have been presented in Table 4.11 and depicted in fig. 4.11. Data related to straw yield (kg ha.$^{-1}$) was infused significantly different intercropping row ratio. The maximum straw yield (kg ha.$^{-1}$) was observed in cluster bean sole 6:1 (T_2) 1606.67 followed by (T_3) 3126.67 and significantly superior over (T_6). The minimum straw yield (kg ha.$^{-1}$) was recorded in pearl millet: cluster bean 8:1 (T_5) 1395.67

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

Data relating to Grain yield (kg ha.$^{-1}$) have been presented in Table 4.11 and depicted in fig. 4.11. Data related to grain yield (kg ha.$^{-1}$) was infused significantly different intercropping row ratio. The maximum grain yield (kg ha.$^{-1}$) was observed in cluster bean 6:1 (T_2) 1606.67 followed by (T_3) 1568 and significantly superior over (T_6). The minimum grain yield (kg ha.$^{-1}$) was recorded in pearl millet: cluster bean 8:1 (T_6) 1395.67.

4.3.2.7 Biological yield

Data relating to biological yield have been presented in Table 4.11 and depicted in fig. 4.11 Data related to grain yield (kg ha.$^{-1}$) was infused significantly different intercropping row ratio. The maximum biological yield (kg ha.$^{-1}$) was observed in cluster bean 6:1 (T_2) 4919.11 followed by (T_3) 4779.77 and significantly superior over (T_6). The minimum biological yield (kg ha.$^{-1}$) was recorded in pearl millet cluster bean 8:1 (T_6) 4233.57

4.3.2.8 Harvest index

The data on harvest index (%) as influenced by different treatments have been presented in Table 4.11 and depicted in fig. 4.11

Data related to harvest index (%) was infused significantly different intercropping row ratio. The maximum harvest index (%) was observed in pearl millet: cluster bean 8:1 (T_6) 432.37 followed by (T_4) 32.77 and significantly superior over cluster bean sole (T_2). The minimum harvest index was recorded in cluster bean sole (T_2) 4233.57

Table -4.11: Effect of planting pattern on seed, straw, biological yields and harvest index of cluster bean

Treatment	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1 -Pearl millet sole	-	-	-	-
T_2 -Cluster bean sole	1606.67	3312.44	4919.11	32.66
T_3 -Pearl millet: cluster bean (2:1)	1568.00	3211.77	4779.77	32.80
T_4 -Pearl millet: cluster bean (4:1)	1508.00	3093.42	4601.42	32.77
T_5 -Pearl millet: cluster bean (6:1)	1458.67	2997.11	4455.78	32.74
T_6 -Pearl millet: cluster bean (8:1)	1395.67	2837.91	4233.57	32.97
SEm$\pm$	2.58	11.21	12.89	0.07
C.D. (P=0.05)	7.55	32.81	37.71	0.19

4.4. Quality of Pearl millet and cluster bean

4.4.1 Nutrient content

4.4.1.1 Nitrogen content plant^{-1}

All the intercropping treatment showed marked influence on the nitrogen percent of both pearl millet grain as well as straw. The data pertaining to nitrogen content plant^{-1} of pearl millet revealed that (Table 4.12 and Fig. 4.12)

The maximum nitrogen content plant^{-1} in (%) pearl millet grain reported under 1.71, pearl millet: cluster bean 6:1 (T_5) and straw 0.60 (T_3), (T_4), (T_8) significantly superior all the treatment combination exception in straw (T_6), (T_5) (T_4) and (T_3) treatment. The minimum nitrogen uptake was (kg ha^{-1}) observed under in (T_3) grain 19.02 and straw 21.88, (T_3) intercropping treatment.

The maximum nitrogen content percent in cluster bean grain 4.04, straw 0.97, total 5.01 kg were observed under pearl millet: cluster bean 6:1 (T_5) significantly superior all the treatment combination treatment. The minimum nitrogen content in grain 3.71, straw 0.84 total 5.01 under pearl millet: cluster bean 6:1 (T_5) observes intercropping treatment.

Table - 4.12: Effect of planting pattern on nitrogen content in pearl millet and cluster bean

Treatment	Pearl millet (%)		Cluster bean (%)	
	Grain	Straw	Grain	Straw
T_1 -Pearl millet sole	1.67	0.58	-	-
T_2 -Cluster bean sole	-	-	3.71	0.84
T_3 -Pearl millet: cluster bean (2:1)	1.70	0.60	3.99	0.94
T_4 -Pearl millet: cluster bean (4:1)	1.70	0.60	4.01	0.95
T_5 -Pearl millet: cluster bean (6:1)	1.71	0.62	4.04	0.97
T_6 -Pearl millet: cluster bean (8:1)	1.70	0.59	3.84	0.90
SEm±	0.01	0.004	0.96	0.06
C.D. (P=0.05)	NS	NS	2.82	0.18

4.4.1.2 Phosphorus content

Data relating to: phosphorus content as affected by different intercropping are presented in Table 4.13 and fig 4.13.

Table - 4.13: Effect of planting pattern on phosphorus content in pearl millet and cluster bean

Treatments	Pearl millet (%)		Cluster bean (%)	
	Grain	Straw	Grain	Straw
T_1 -Pearl millet sole	0.35	0.19	-	-
T_2 -Cluster bean sole	-	-	0.27	0.10
T_3 -Pearl millet: cluster bean (2:1)	0.36	0.20	0.29	0.09
T_4 -Pearl millet: cluster bean (4:1)	0.35	0.19	0.30	0.10
T_5 -Pearl millet: cluster bean (6:1)	0.36	0.19	0.31	0.11
T_6 -Pearl millet: cluster bean (8:1)	0.35	0.20	0.28	0.10
SEm$\pm$	0.004	0.002	0.01	0.016
C.D. (P=0.05)	NS	NS	0.02	0.01

Different intercropping system cause the non significant differences were observed in phosphorus content. The maximum phosphorus content in grain 0.31 was recorded in pearl millet: cluster bean 6:1 (T_5), straw 0.11 (T_2). Minimum phosphorus content in grain 0.35 were observed in (T1), (T_4), (T_6) treatment.

4.4.1. Potassium content

All the intercropping treatment showed marked influence on the potassium percent of both pearl millet grain as well as straw. The data pertaining to potassium content plant^{-1} of pearl millet revealed that (Table 4.14 and Fig. 4.14). The maximum potassium content plant^{-1} in pearl millet grain 0.592 (%) and straw 1.641 (%) reported under pearl millet: cluster bean 6:1 (T_5) significantly superior all the treatment combination exception in straw (T_4), (T_3) (T_2) and (T_6) treatment. The minimum potassium content was observed under in pearl millet sole (T_1) grain 0.462 (%) and straw (T_6) 1.608 intercropping treatment.

The maximum potassium content percent in cluster bean grain 0.169, straw 0.620 were observed under pearl millet: cluster bean 6:1 (T_5) significantly superior all the treatment combination treatment. The minimum potassium content in grain 0.159, straw 0.591 under cluster bean sole (T_1) observes intercropping treatment.

Table - 4.14: Effect of planting pattern on potassium content in pearl millet and cluster bean

Treatments	Pearl millet (%)		Cluster bean (%)	
	Grain	Straw	Grain	Straw
T_1 -Pearl millet sole	0.462	1.615	-	-
T_2 -Cluster bean sole	-	-	0.159	0.591
T_3 -Pearl millet: cluster bean (2:1)	0.505	1.585	0.166	0.618
T_4 -Pearl millet: cluster bean (4:1)	0.522	1.613	0.167	0.619
T_5 -Pearl millet: cluster bean (6:1)	0.592	1.641	0.169	0.620
T_6 -Pearl millet: cluster bean (8:1)	0.486	1.608	0.162	0.617
SEm$\pm$	0.015	0.005	0.003	0.004
C.D. (P=0.05)	0.003	0.014	0.008	0.011

4.4.2 Nutrient uptake

The data relating to the nitrogen, phosphorus uptake of pearl millet and cluster bean grain and straw and protein content in grain g have been presented in Table 4.14 and 4.15 and depicted in Fig. 4.14 and Fig. 4.15

4.4.2.1 Nitrogen uptake

All the intercropping treatment showed marked influence on the nitrogen percent of both pearl millet grain as well as straw. The data pertaining to nitrogen uptake (kg ha^{-1}) of pearl millet revealed that (Table 4.15 and Fig. 4.15). The maximum nitrogen uptake in pearl millet grain reported under (26.02 kg ha^{-1}) pearl millet sole (T_1), straw (30.20 kg ha^{-1}) pearl millet sole (T_1), total (5.22 kg ha^{-1}) pearl millet sole (T_1) significantly superior all the treatment combination exception in straw (T_6), (T_5) (T_4) and (T_3) treatment. The minimum nitrogen uptake was (kg ha^{-1}) observed under in (T_3) grain (19.02 kg ha^{-1}), (T_3) straw (21.88 kg ha^{-1}), (T_3) total (40.92 kg ha^{-1}) intercropping treatment.

The maximum nitrogen uptake (kg ha.$^{-1}$) in cluster bean grain 59.61 kg (T_1), straw 30.19 kg (T_3), total 92.87 kg were observed under pearl millet: cluster bean 2:1 (T_3) significantly superior all the treatment combination treatment. The minimum nitrogen uptake in grain (53.60 kg ha^{-1}) straw (25.55 kg ha^{-1}) total (79.51 kg ha^{-1}) under pearl millet: cluster bean 8:1 (T_6) observes intercropping treatment.

Table - 4.15: Effect of planting pattern on nitrogen uptake by pearl millet and cluster bean

Treatment	Pearl millet (kg ha.$^{-1}$)			Cluster bean (kg ha.$^{-1}$)		
	Grain	Straw	Total	Grain	Straw	Total
T_1 -Pearl millet sole	26.02	30.20	56.22	-	-	-
T_2 -Cluster bean sole	-	-	-	59.61	27.73	87.34
T_3 -Pearl millet: cluster bean (2:1)	19.04	21.88	40.92	62.62	30.19	92.81
T_4 -Pearl millet: cluster bean (4:1)	22.16	25.38	47.54	60.52	29.50	90.02
T_5 -Pearl millet: cluster bean (6:1)	24.61	28.00	52.61	58.98	28.97	87.95
T_6 -Pearl millet: cluster bean (8:1)	25.57	29.61	55.18	53.60	25.55	79.15
SEm±	0.19	0.23	0.35	0.96	1.43	1.81
C.D. (P=0.05)	0.57	0.66	1.03	2.82	4.19	5.28

4.4.2.2 Phosphorus uptake

All the intercropping treatment showed marked influence on the phosphorus (kg ha^{-1}) of both pearl millet and cluster bean grain as well as straw. The data pertaining to phosphorus uptake of pearl millet revealed that (Table 4.16 and Fig. 4.16). The maximum phosphorus uptake in grain (5.43 kg ha^{-1}), straw (6.94 kg ha^{-1}) and total (15.37 kg ha^{-1}) were observed under (T_1) Pearl millet (sole) significantly superior all the treatment combination exception in straw (T_6) treatment. The minimum phosphorus uptake in grain (2.89 kg ha^{-1}) straw (2.89 kg ha^{-1}) and total (6.85 kg ha^{-1}) were observed under (T_6) pearl millet: cluster bean (8:1) row ratio intercropping treatment. The maximum phosphorus uptake in cluster bean grain (4.59 kg ha^{-1}) under pearl millet: cluster bean (T_3) and straw (3.48 kg ha^{-1}) or total (4.30 kg ha^{-1}) were observed in under (T_2) cluster bean sole significantly superior all the treatment combination treatment. The minimum phosphorus uptake in grain (3.96 kg ha^{-1}) straw (2.89 kg ha^{-1}) and total (6.65 kg ha^{-1}) were observed under pearl millet: cluster bean 8:1 (T_6) row ratio intercropping treatment.

Table -4.16: Effect of planting pattern on phosphorus uptake by pearl millet and cluster bean

Treatments	Pearl millet (kg ha.$^{-1}$)			Cluster bean (kg ha.$^{-1}$)		
	Grain	Straw	Total	Grain	Straw	Total
T_1 -Pearl millet sole	5.43	9.94	15.37	-	-	-
T_2 -Cluster bean sole	-	-	-	4.35	3.48	7.83
T_3 -Pearl millet: cluster bean (2:1)	4.00	7.16	11.16	4.59	3.04	7.63
T_4 -Pearl millet: cluster bean (4:1)	4.62	8.25	12.87	4.52	3.14	7.66
T_5 -Pearl millet: cluster bean (6:1)	5.17	8.98	14.15	4.56	3.03	7.59
T_6 -Pearl millet: cluster bean (8:1)	5.28	9.76	15.04	3.96	2.89	6.85
SEm$\pm$	0.05	0.10	0.15	0.13	0.07	0.12
C.D. (P=0.05)	0.15	030	0.43	0.39	0.22	0.36

4.4.2. Potassium uptake

All the intercropping treatment showed marked influence on the potassium (kg ha^{-1}) of both pearl millet and cluster bean grain as well as straw. The data pertaining to potassium uptake of pearl millet revealed that (Table 4.17 and Fig. 4.17). The maximum potassium uptake by straw (82.43 kg ha^{-1}) under pearl millet: cluster bean 6:1 (T_6) and total uptake (89.60 kg ha^{-1}) were observed under (T_1) Pearl millet (sole) significantly superior all the treatment. However, potassium uptake by grain (8.53 kg ha^{-1}) was highest under (T_5) pearl millet: cluster bean (6:1). The maximum phosphorus uptake by cluster bean grain (2.54 kg ha^{-1}) under (T_4) pearl millet: cluster bean (4:1) while potassium uptake by straw (19.84 kg ha^{-1}) or total uptake 22.44 kg ha^{-1} were observed under (T_3) pearl millet: cluster bean (2:1) it was statistically at par of cluster bean sole.

Table - 4.17: Effect of planting pattern on potassium uptake by pearl millet and cluster bean

Treatments	Pearl millet (kg ha.$^{-1}$)			Cluster bean (kg ha.$^{-1}$)		
	Grain	Straw	Total	Grain	Straw	Total
T_1 -Pearl millet sole	7.17	82.43	89.60	-	-	-
T_2 -Cluster bean sole	-	-	-	2.54	19.56	22.11
T_3 -Pearl millet: cluster bean (2:1)	5.65	58.04	63.70	2.59	19.84	22.44
T_4 -Pearl millet: cluster bean (4:1)	6.79	68.47	75.26	2.54	19.13	21.68
T_5 -Pearl millet: cluster bean (6:1)	8.53	77.58	86.11	2.47	18.58	21.05
T_6 -Pearl millet: cluster bean (8:1)	7.31	79.41	86.73	2.25	17.50	19.76
SEm$\pm$	0.04	0.23	0.21	0.04	0.12	0.11
C.D. (P=0.05)	0.12	0.68	0.63	0.12	0.35	0.34

4.4.3 Protein content in grain

All the intercropping patterns showed marked influence on the Protein content per cent of both Pearl millet grain as well as straw. The data pertaining to Protein content of cluster bean revealed that (Table 4.18 and Fig. 4.18). In intercropping patterns improved the Pearl millet grain protein content significantly. Pearl millet: cluster bean 6:1 (T_5) method recorded significantly higher protein content in grain. The maximum protein content in grain 11.94 per cent was observed under pearl millet: cluster bean 6:1 (T_5), followed by (T_4)11.46 and significantly superior over (T_1) respectively in intercropping. The minimum protein content in grain 11.06 per cent was observed in case of (T_1) Pearl millet sole in intercropping.

Data related to protein content was infused significantly different intercropping row ratio. The maximum protein content was observed in pearl millet: cluster bean 6:1 (T_5) 25.23 followed by (T_4) 24.95 and significantly superior over (T_1). The minimum protein content was recorded in cluster bean sole 23.43.

Table - 4.18: Effect of planting pattern on protein content in pearl millet and cluster bean

Treatment	Pearl millet (%)	Cluster bean (%)
T_1 -Pearl millet sole	11.06	-
T_2 -Cluster bean sole	-	23.43
T_3 -Pearl millet: cluster bean (2:1)	11.35	24.80
T_4 -Pearl millet: cluster bean (4:1)	11.46	24.95
T_5 -Pearl millet: cluster bean (6:1)	11.94	25.23
T_6 -Pearl millet: cluster bean (8:1)	11.24	24.76
SEm±	0.02	0.45
C.D.(P=0.05)	0.07	1.33

4.5 Indices

4.5.1 Pearl millet equivalent yield

Data presented in Table 4.19 indicated that intercropping treatments significantly influenced the pearl millet grain equivalent yield. The maximum mean pearl millet grain equivalent yield (4767.24 kg ha^{-1}) was obtained under pearl millet sole (T_1) significantly higher than all other treatments. The minimum mean pearl millet grain equivalent yield (4256.24 kg ha^{-1}) was obtained under pearl millet: cluster bean 2:1 (T_3) significantly lower than all other treatments.

4.5.2 Land equivalent ratio (LER)

Data presented in Table 4.19 indicated that intercropping treatments significantly influenced the pearl millet land equivalent ratio. The maximum mean pearl millet land equivalent ratio 2.12 was obtained under pearl millet+ cluster bean 4:1 (T_4), significantly higher than all other treatments. The minimum mean pearl millet land equivalent ratio (1.70) was obtained under (T_3) pearl millet: cluster bean 2:1 (T_3) significantly lower than all other treatments.

Table -4.19: LER and PGER in pearl millet and cluster bean planting pattern

Treatment	PGER	LER
T_1 -Pearl millet sole	4767.24	1.0
T_2 -Cluster bean sole	-	1.0
T_3 -Pearl millet: cluster bean (2:1)	4256.24	1.70
T_4 -Pearl millet: cluster bean (4:1)	4318.19	2.12
T_5 -Pearl millet: cluster bean (6:1)	4358.44	2.07
T_6 -Pearl millet: cluster bean (8:1)	4296.73	2.00
SEm±	6.17	0.014
C.D.(P=0.05)	18.09	0.0048

4.6 Economics

The economics worked out in terms of net returns per hectare and B:C ratio are presented in Table 4.20

4.6.1 Net returns (Rs. ha^{-1})

Data presented in Table 4.20 showed that intercropping treatment has maximum net return (Rs. 48441 ha^{-1}) in pearl millet: cluster bean 6:1 (T_5), statistically at par with 4:1, 2:1 and 6:2 row ratio treatments and were significantly higher than sole (T_1) pearl millet sole. The maximum net return (Rs.47234 ha^{-1}) was observed under pearl millet: cluster bean 6:1 (T_5), whereas pearl millet: cluster bean 4:1 (T_4) (47471), pearl millet: cluster bean 8:1 (T_6) (47234) pearl millet: cluster bean 2:1 (T_3) 36788 and cluster bean sole (T_2) in intercropping. The minimum net return in observed in case of (T_1) pearl millet sole (Rs. 28713 ha^{-1}) in intercropping.

Table - 4.20: Economic in pearl millet and cluster bean intercropping

Treatment	Pearl millet			Cluster bean			Guava	Total Income	Total Cost	Net Income	B:C Ratio
	Grain	Straw	Total	Grain	Straw	Total					
T_1 -Pearl millet sole	13990	7656	21646	-	-	-	30500	52146	23433	28713	2.22
T_2 -Cluster bean sole	-	-	-	28920	4968	338889	30500	64388	27600	36788	2.33
T_3 -Pearl millet: cluster bean (2:1)	1008	5494	15576	28224	4817	33042	30500	79118	32800	46318	2.41
T_4 -Pearl millet: cluster bean (4:1)	11719	6367	18087	27144	4640	31784	30500	80371	32900	47471	2.44
T_5 - Pearl millet: cluster bean (6:1)	12969	7090	20060	26256	4495	30752	30500	81311	32870	48441	2.47
T_6 –Pearl millet: cluster bean (8:1)	13548	7406	20955	25122	4256	29379	30500	80834	33600	47234	2.40
SEm$\pm$	22.77	23.73	43.77	46.42	16.82	57.85	57.85	-	-	-	-
C.D. (P=0.05)	66.63	69.44	128.07	135.82	49.22	169.27	169.27	-	-	-	-

4.6.2 B:C ratio

Data presented in Table 4.20 showed that intercropping treatment has maximum B:C ratio (2.47) in pearl millet: cluster bean 6:1 (T_5), statistically at par with 4:1, 2:1 and 8:2 row ratio treatments and were significantly higher than cluster bean sole (T_2) and (T_1) pearl millet sole. The maximum B:C ratio (2.47) was observed under pearl millet: cluster bean 6:1 (T_5), whereas pearl millet: cluster bean4:1(T_4), pearl millet: cluster bean 2:1 (T_2), pearl millet: cluster bean 8:1 (T_6), respectively in intercropping. The minimum net return in observed in case of (T_1) pearl millet sole (T_1) (2.22) in intercropping.

Figure 4.1: Effect of planting pattern on plant height of pearl millet.

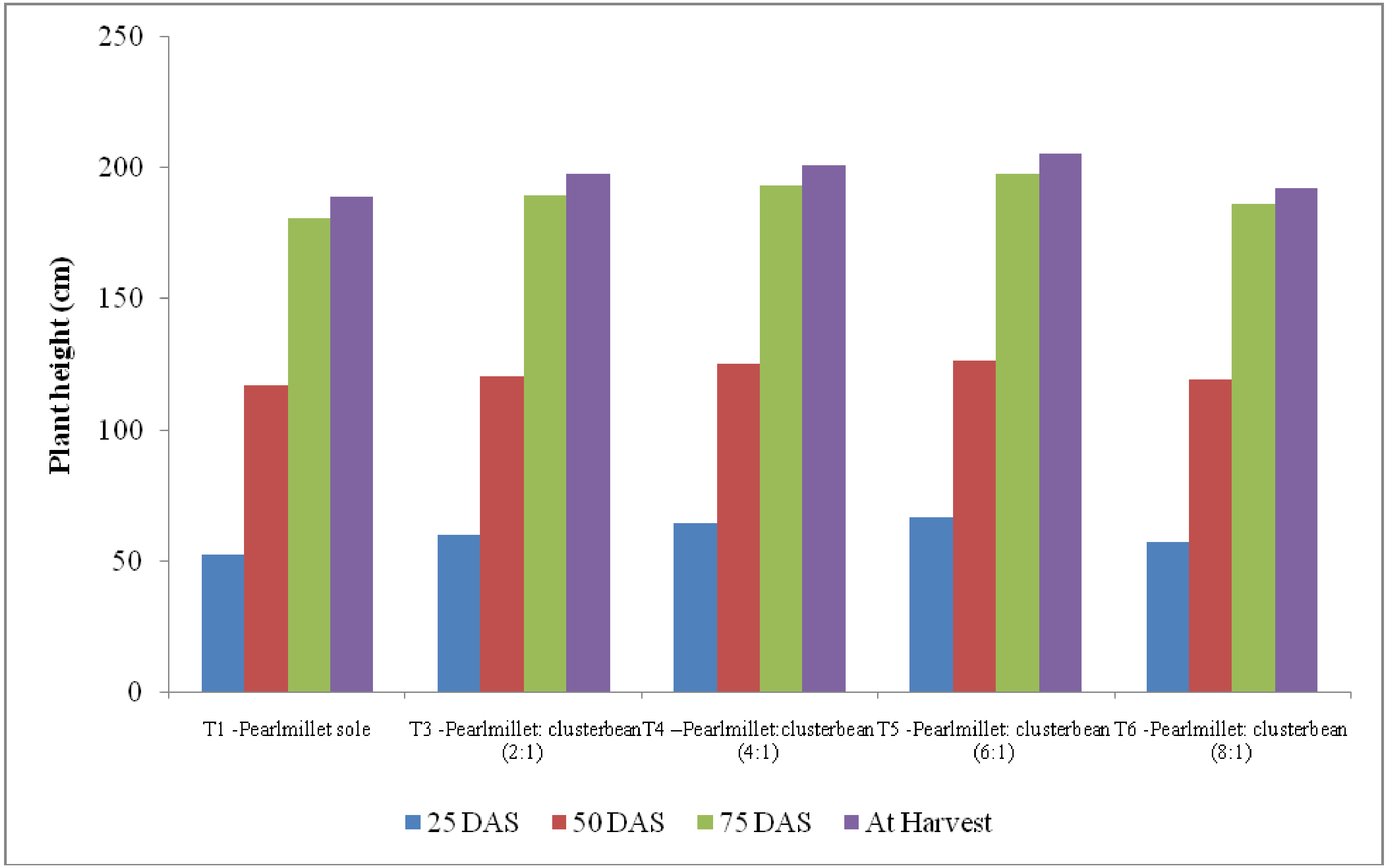


Figure 4.2: Effect of planting pattern on number of leaves pearl millet

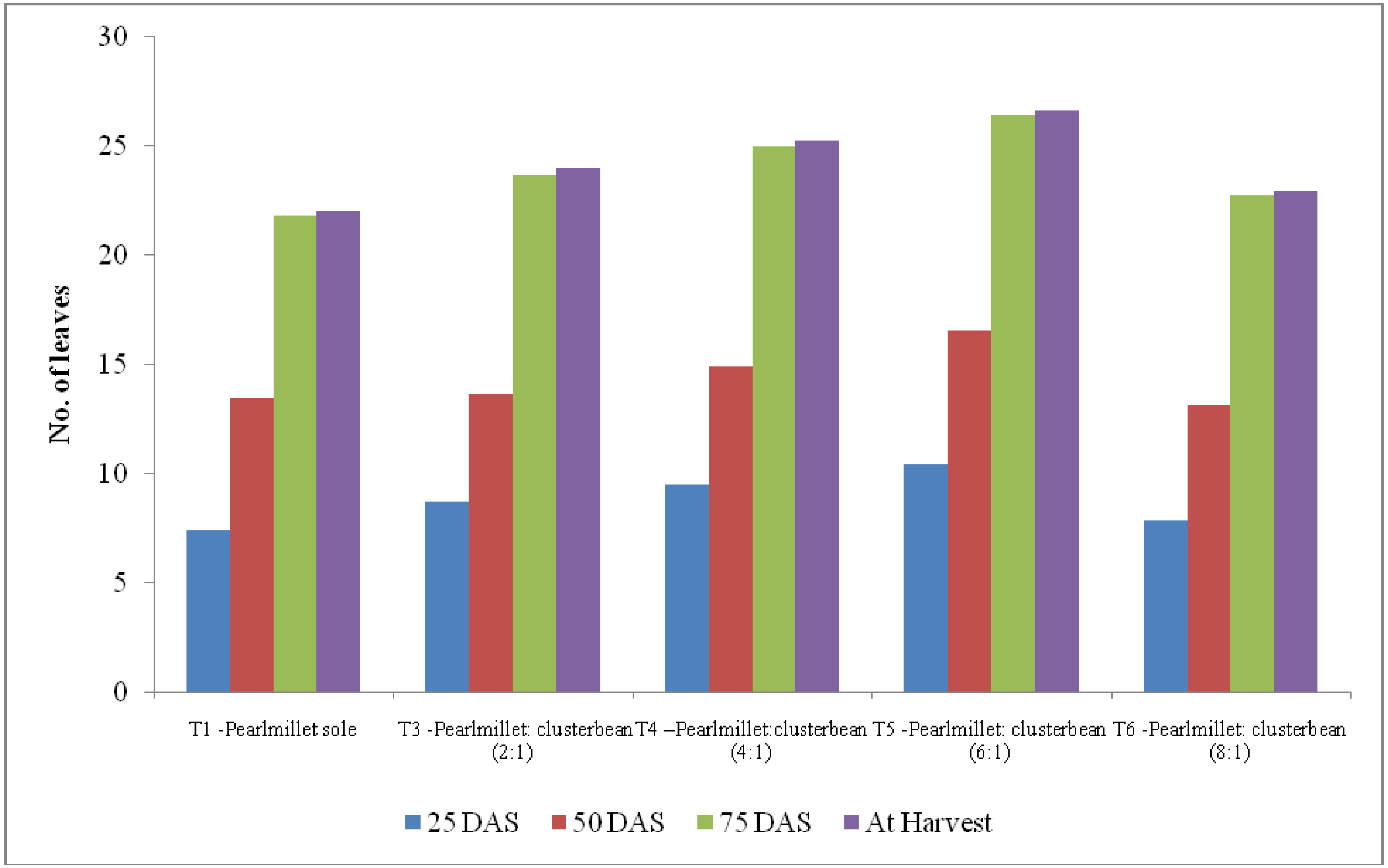


Figure 4.3: Effect of planting pattern on number of tillers pearl millet

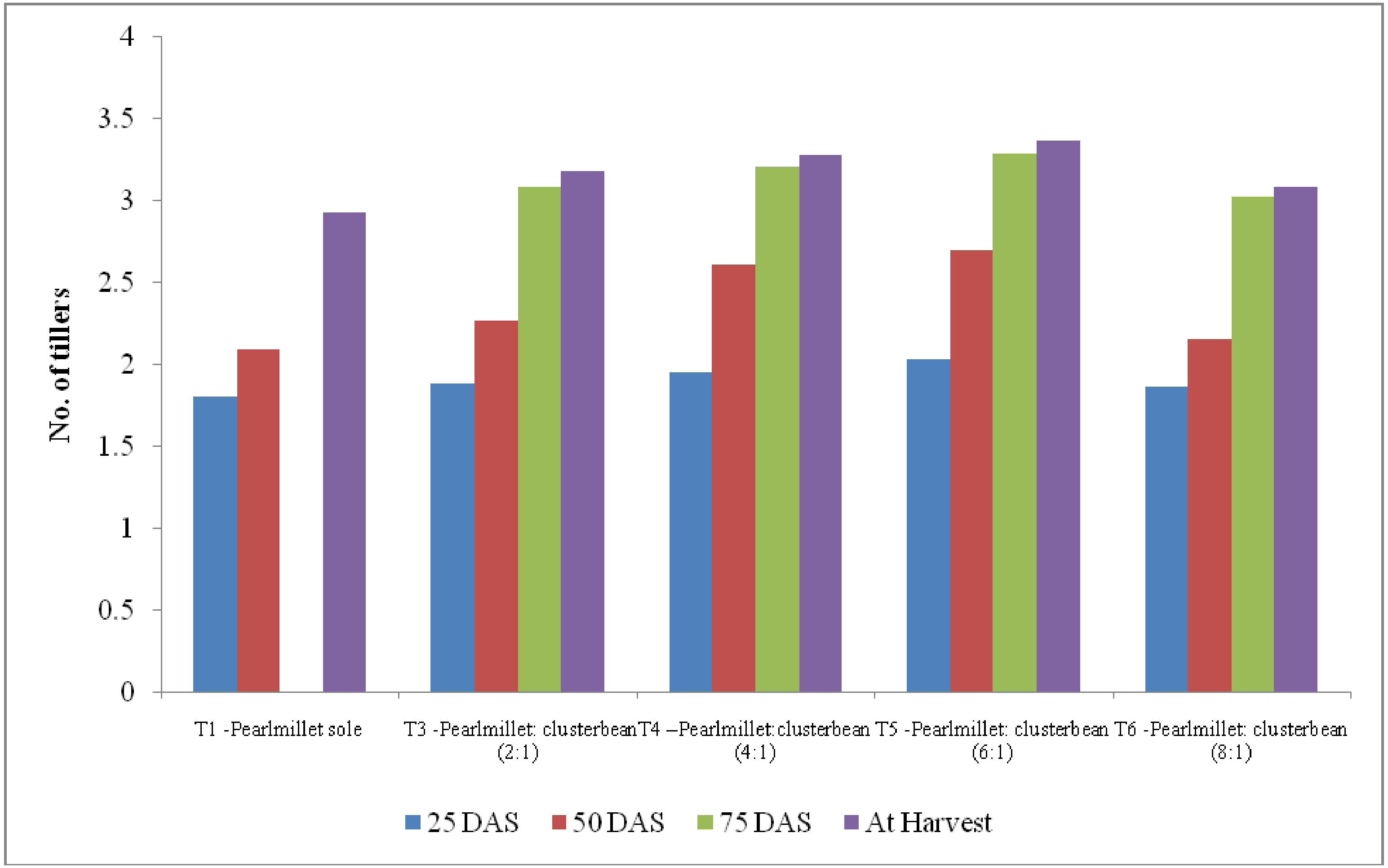


Figure 4.4: Effect of planting pattern on dry weight (g) of pear millet

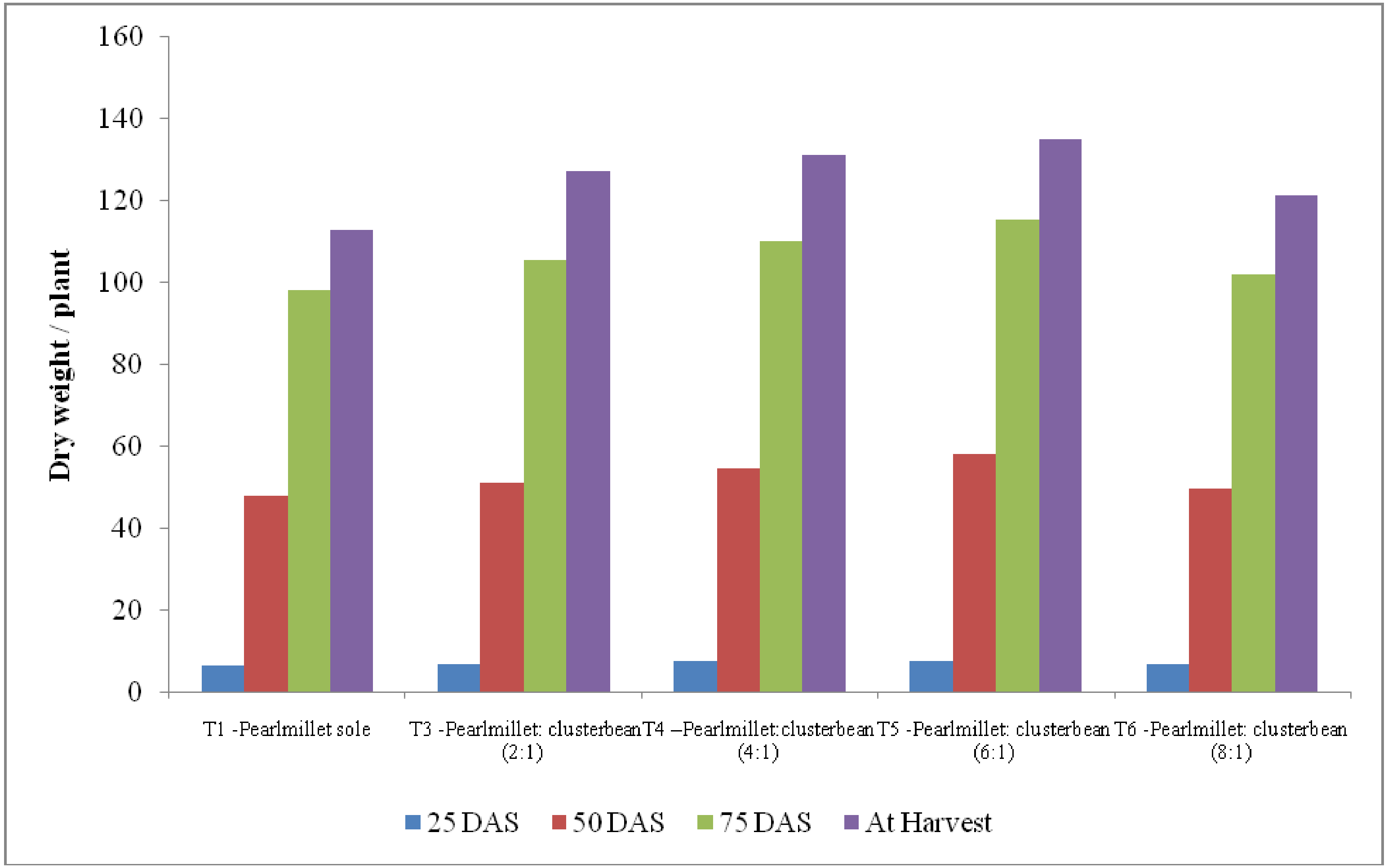


Figure 4.5: Effect of planting pattern on yield attributes of pearl millet

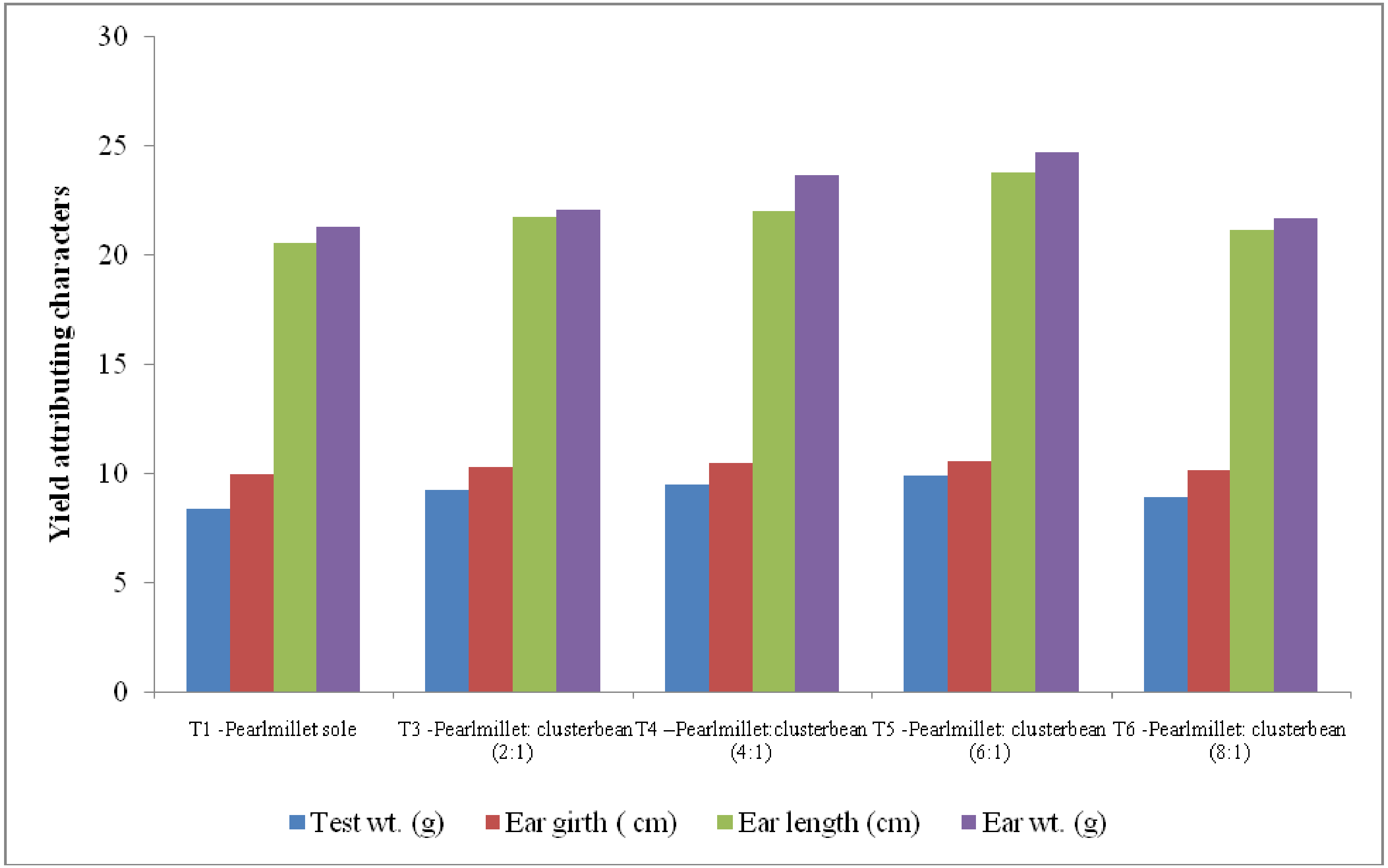


Figure 4.6: Effect of planting pattern on grain, straw, biological yields and harvest index of pearl millet

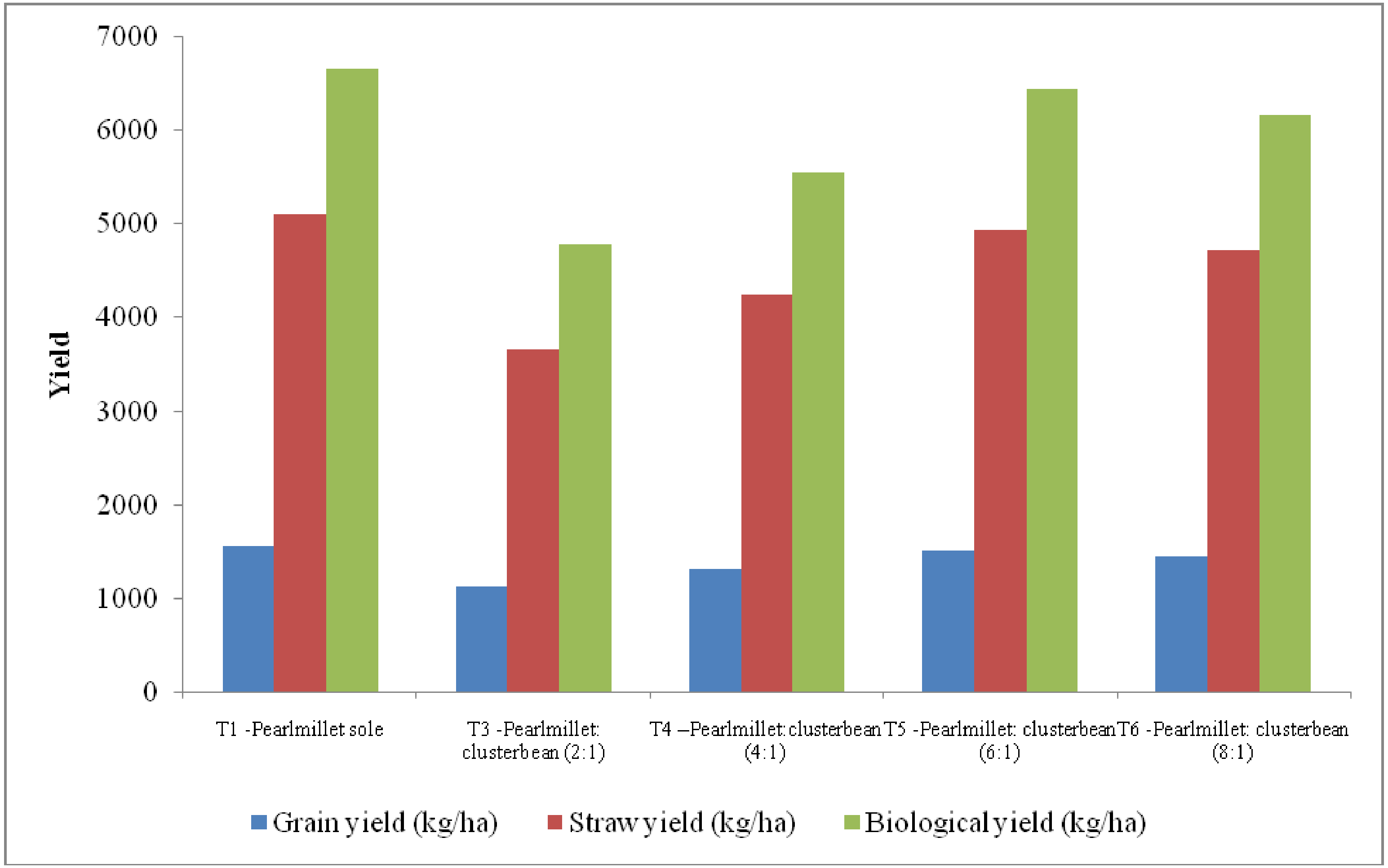


Figure 4.7: Effect of planting pattern on plant height of cluster bean

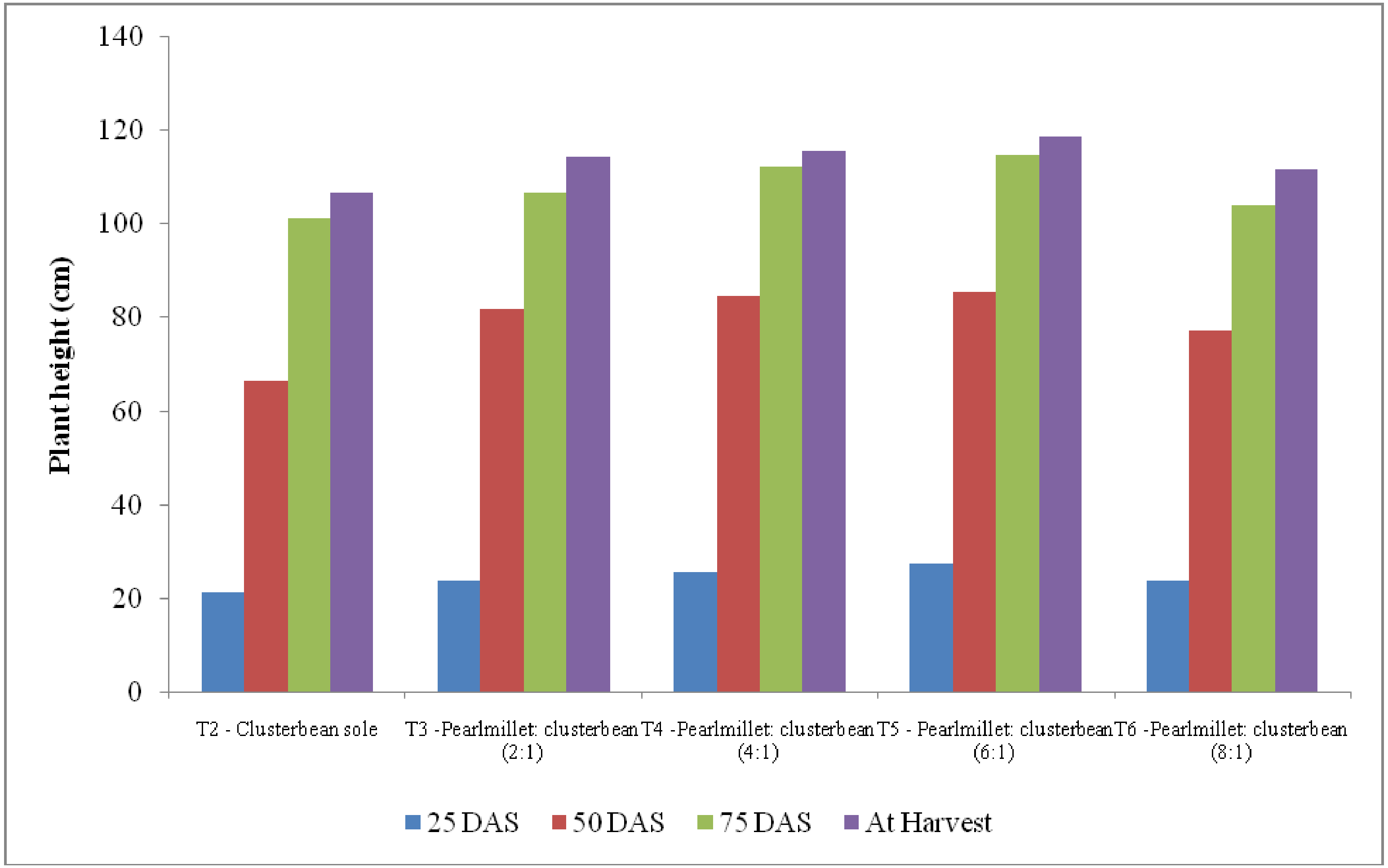


Figure 4.8: Effect of planting pattern on number of branches of cluster bean

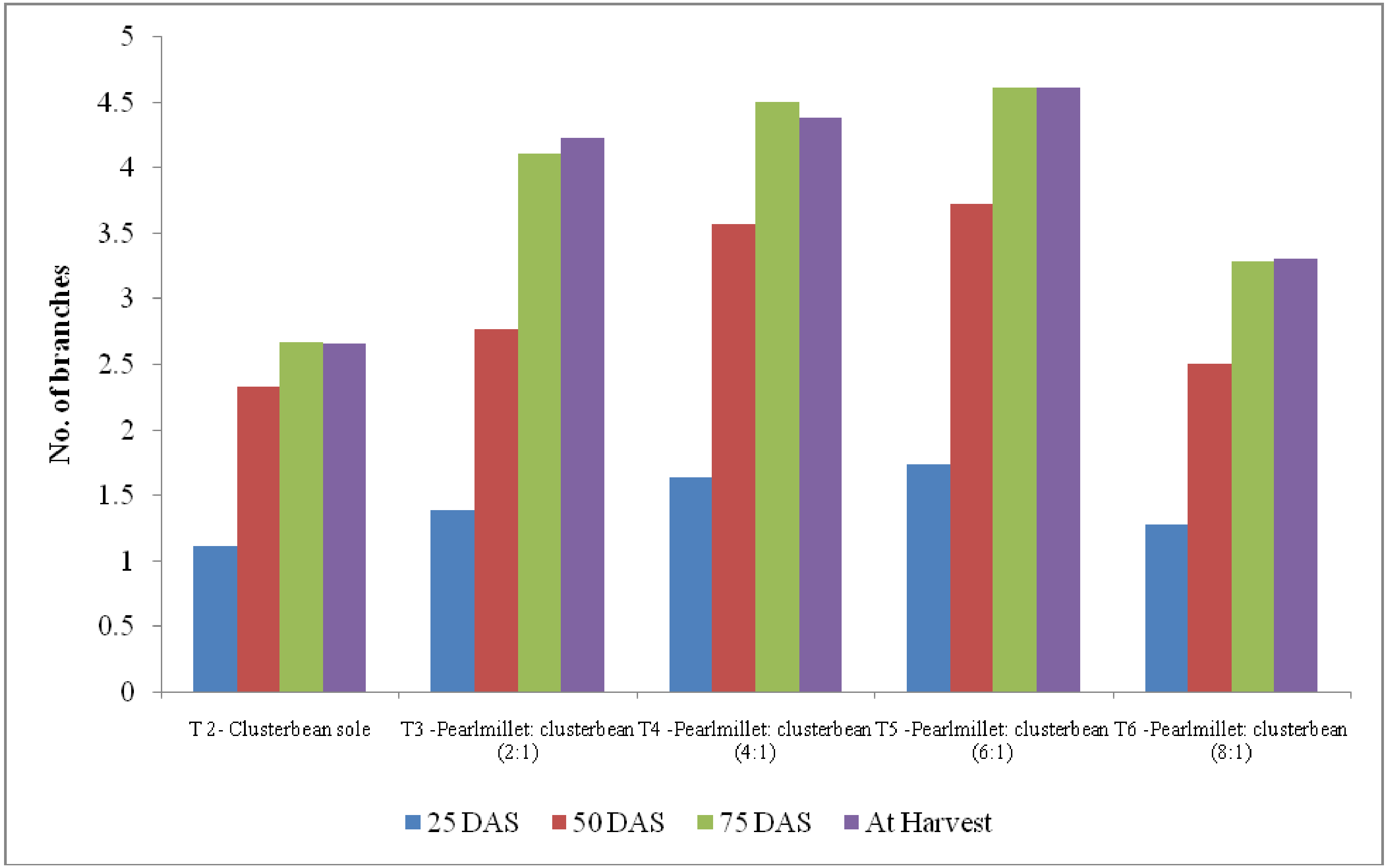


Figure 4.9: Effect of planting pattern on dry weight of cluster bean

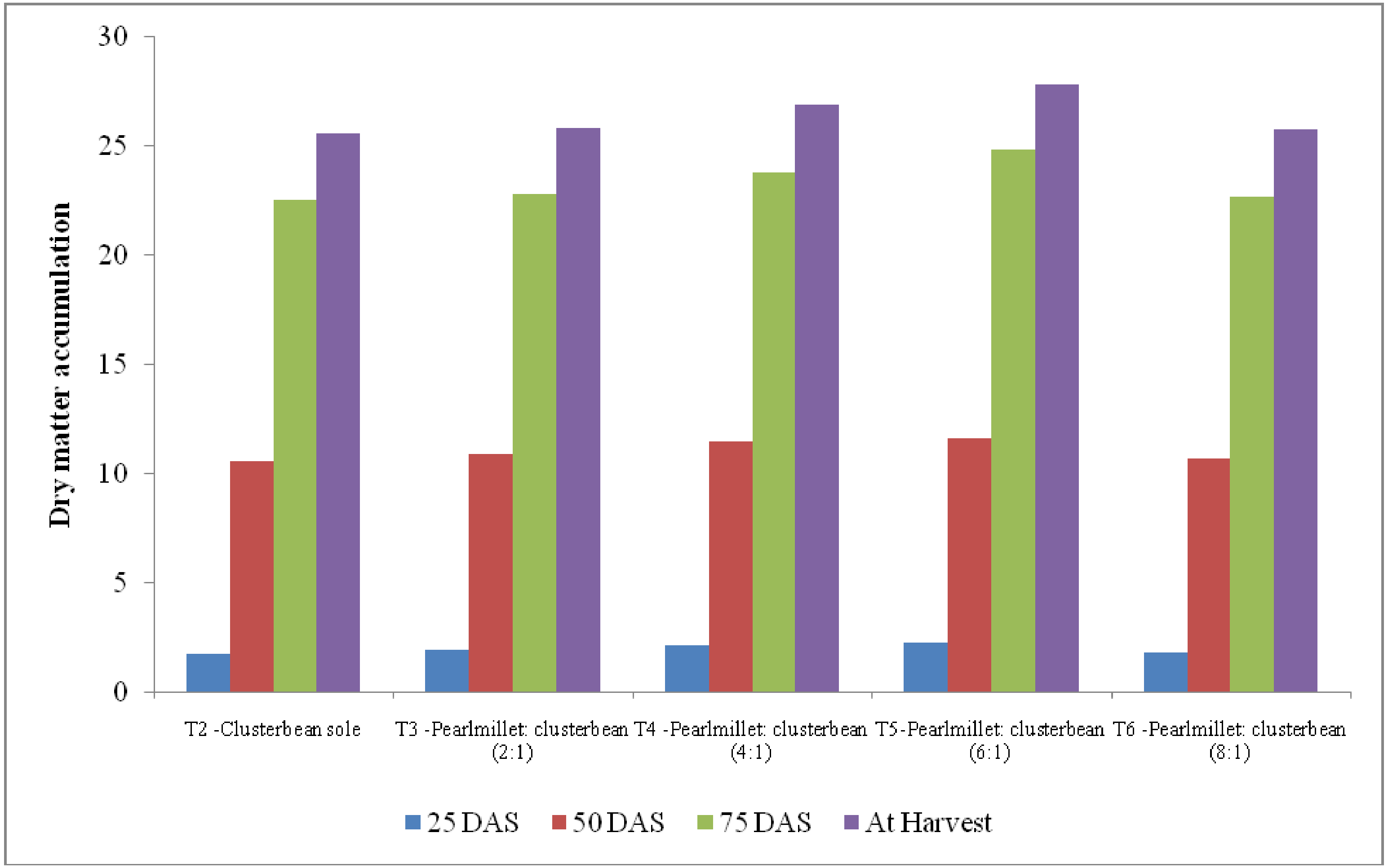


Figure 4.10: Effect planting pattern on yield attributes of cluster bean

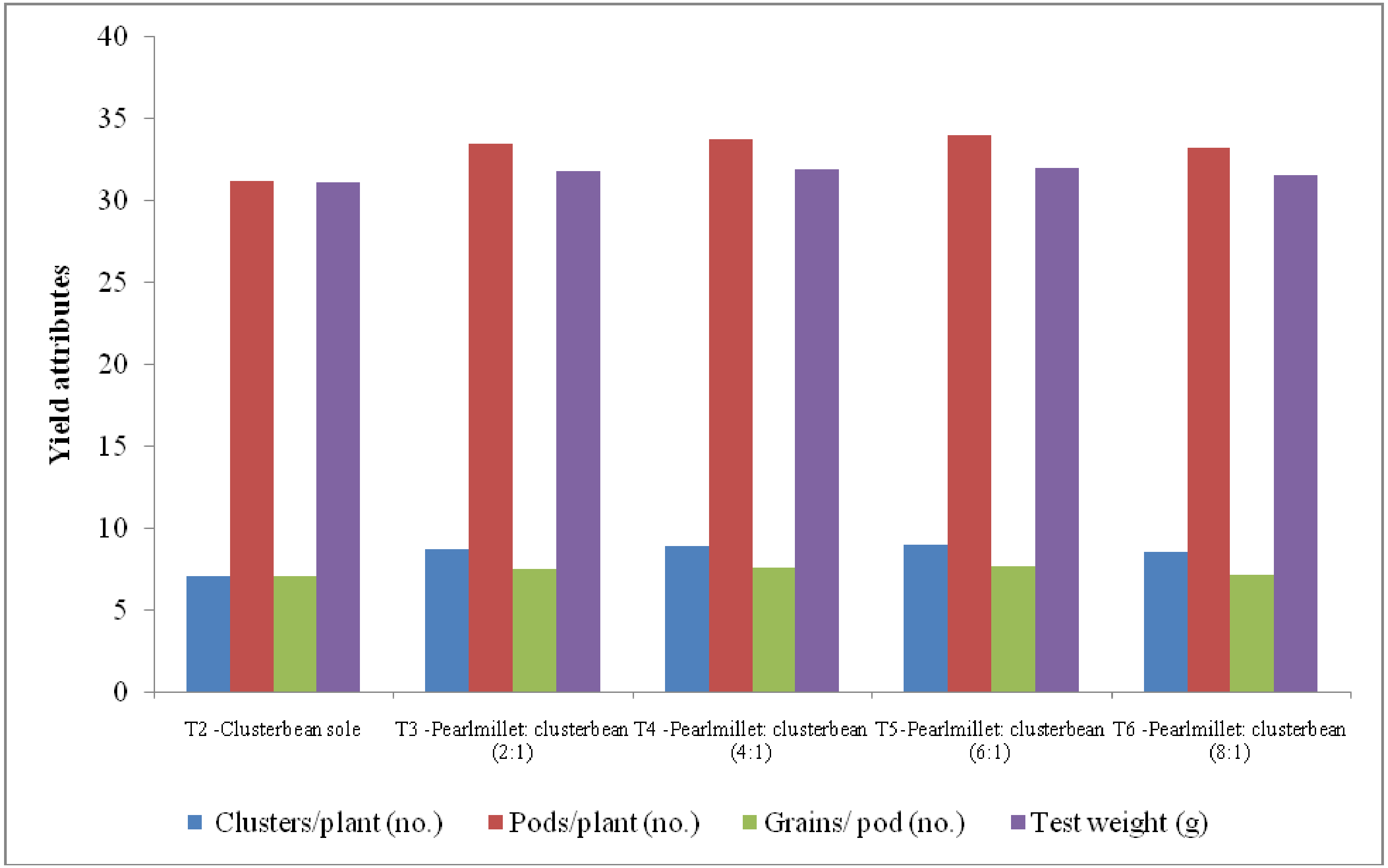


Figure 4.11: Effect of planting pattern on seed, straw, biological yields and harvest index of cluster bean

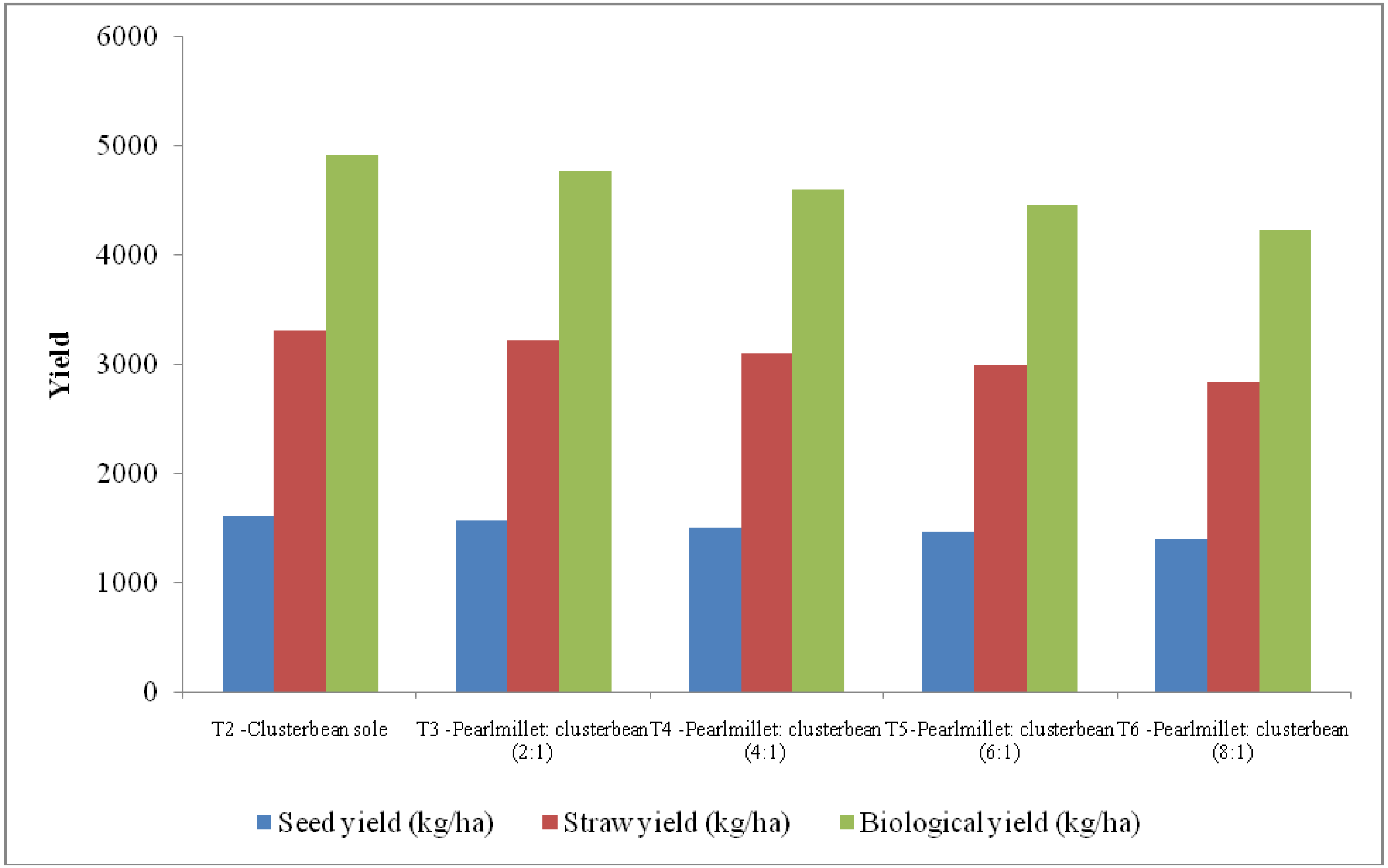


Figure 4.12 : Effect of planting pattern on nitrogen content in pearl millet and cluster bean

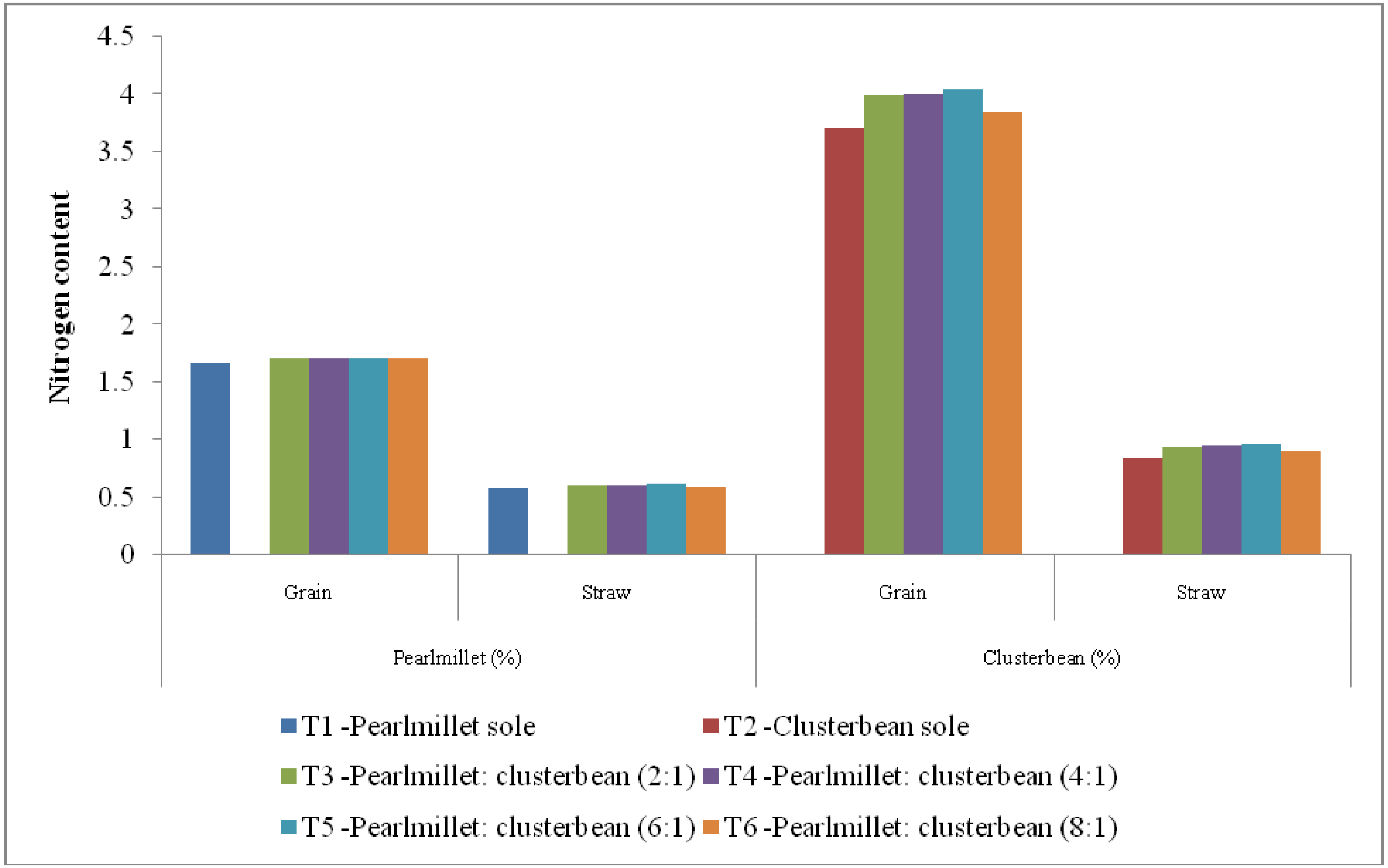


Figure 4.13 : Effect of planting pattern on phosphorus content in pearl millet and cluster bean

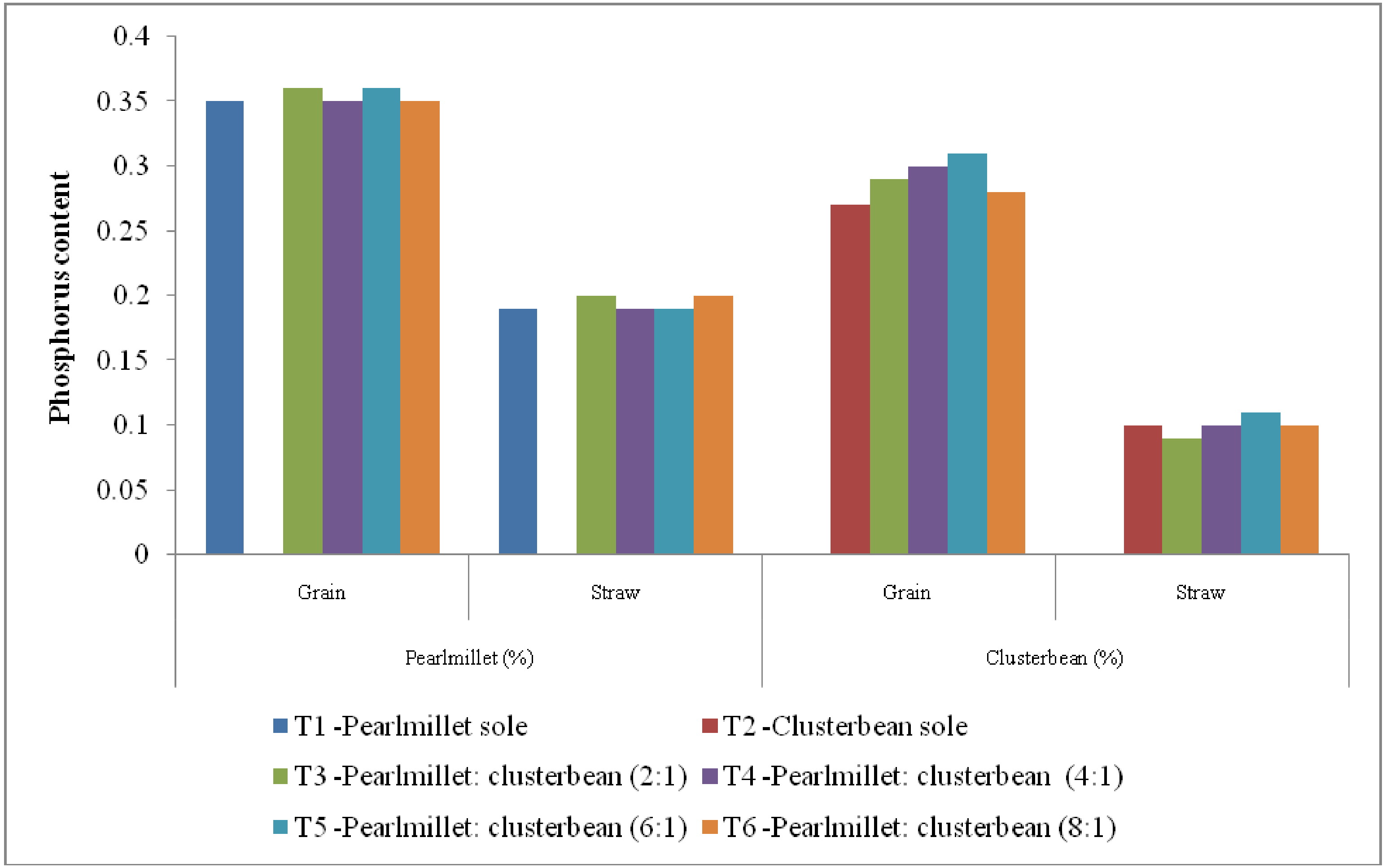


Figure 4.14: Effect of planting pattern on potassium content in pearl millet and cluster bean

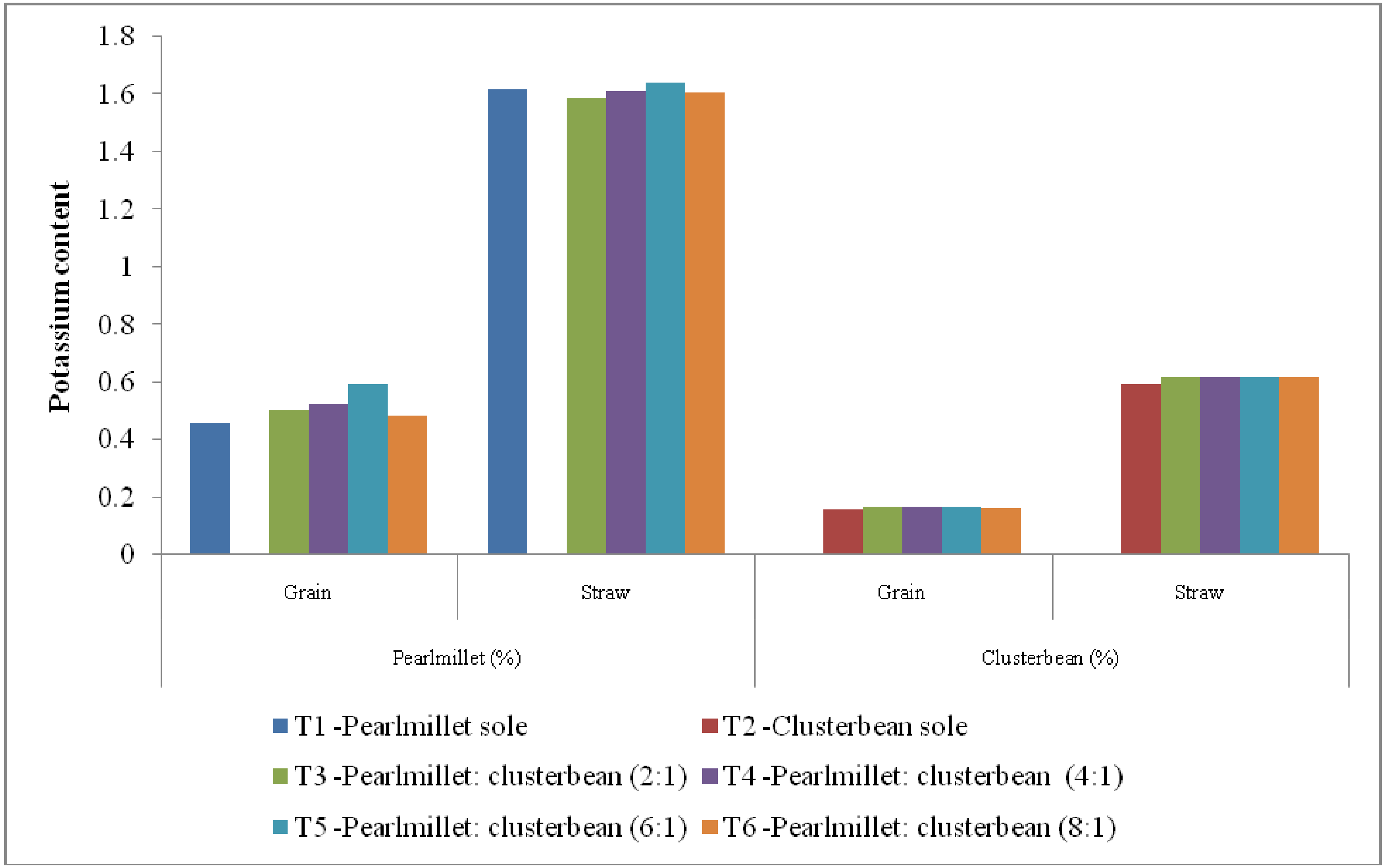


Figure 4.15 : Effect of planting pattern on nitrogen uptake by pearl millet and cluster bean

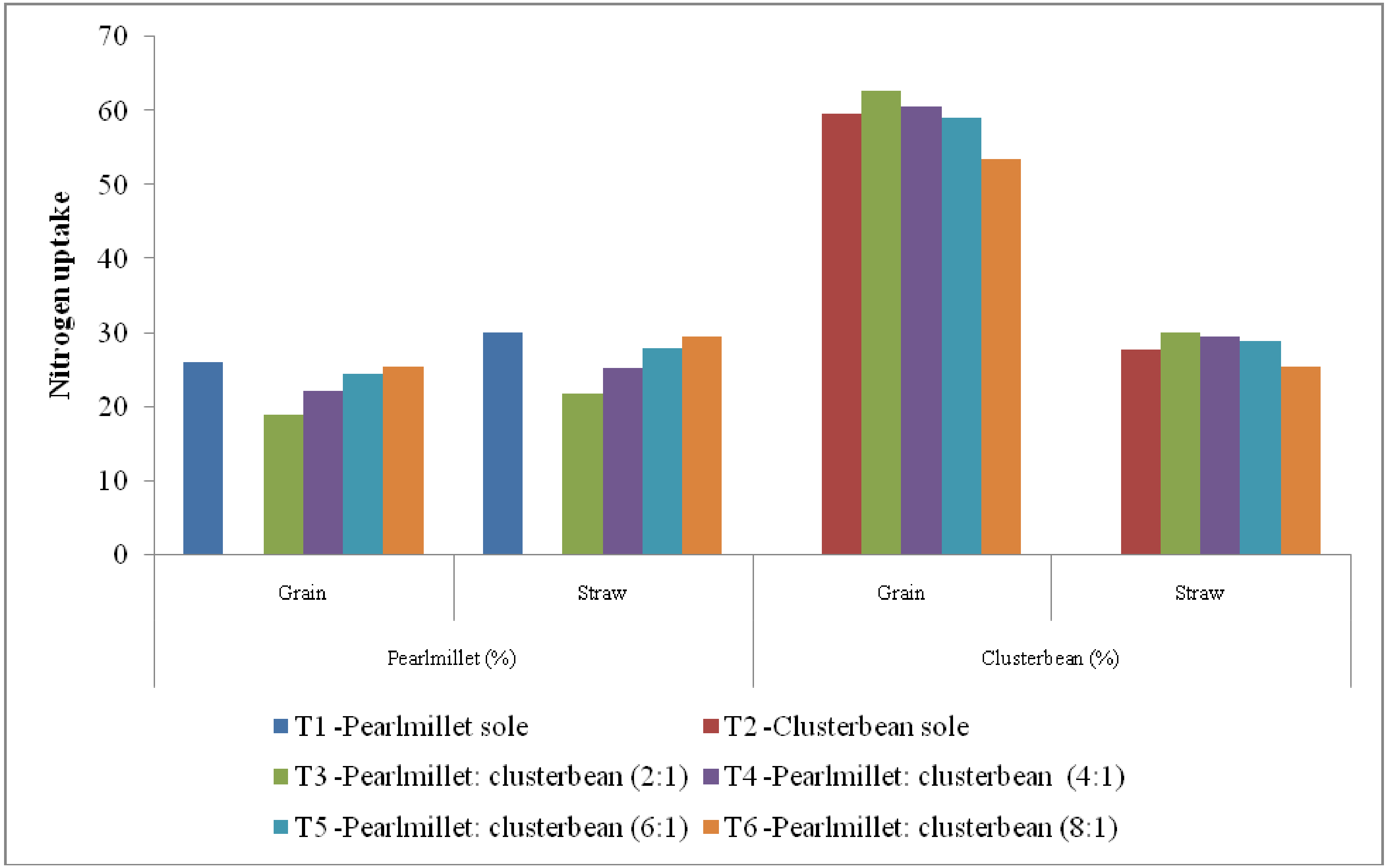


Figure 4.16 : Effect of planting pattern on phosphorus uptake by pearl millet and cluster bean

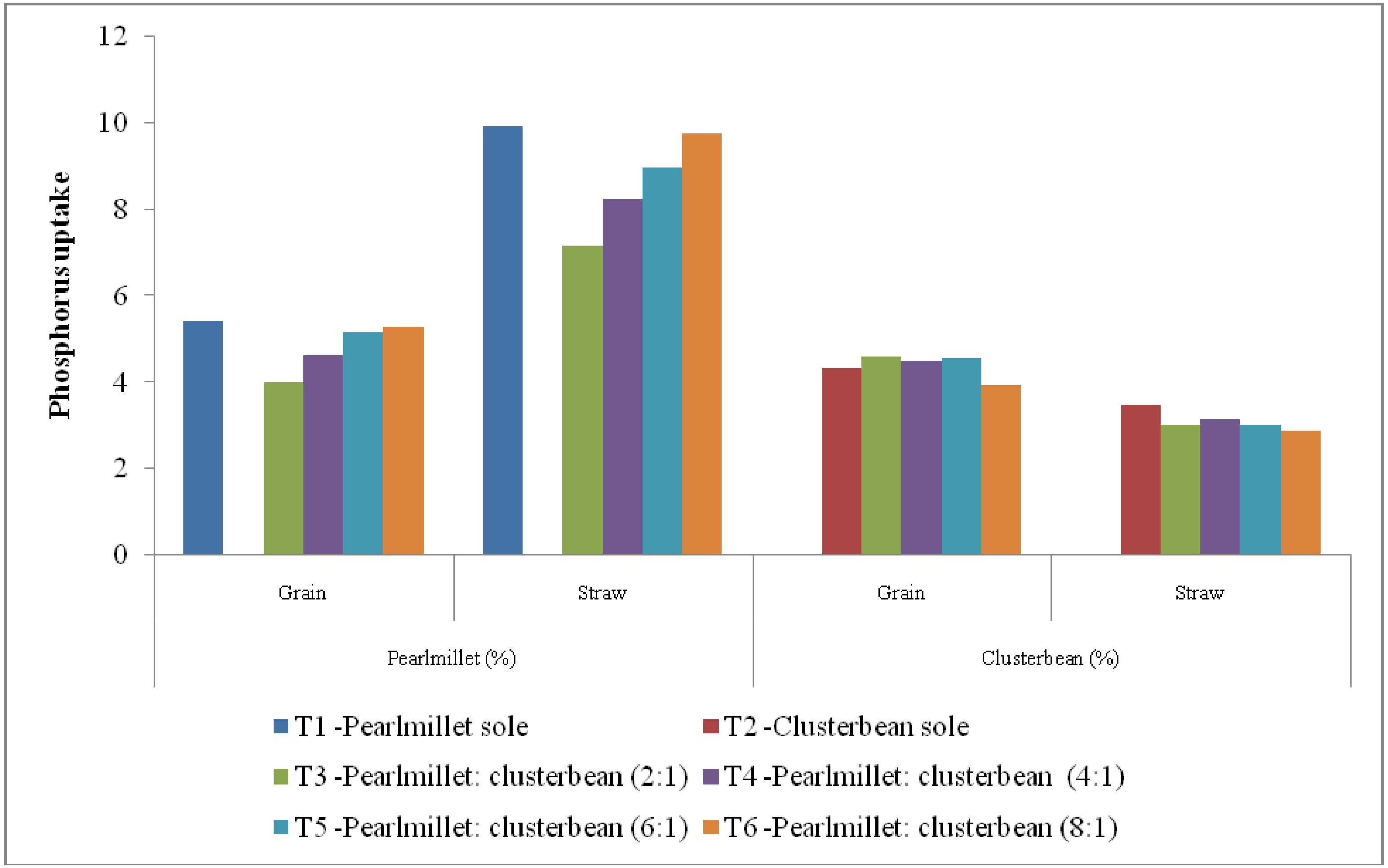


Figure 4.17 : Effect of planting pattern on potassium uptake by pearl millet and cluster bean

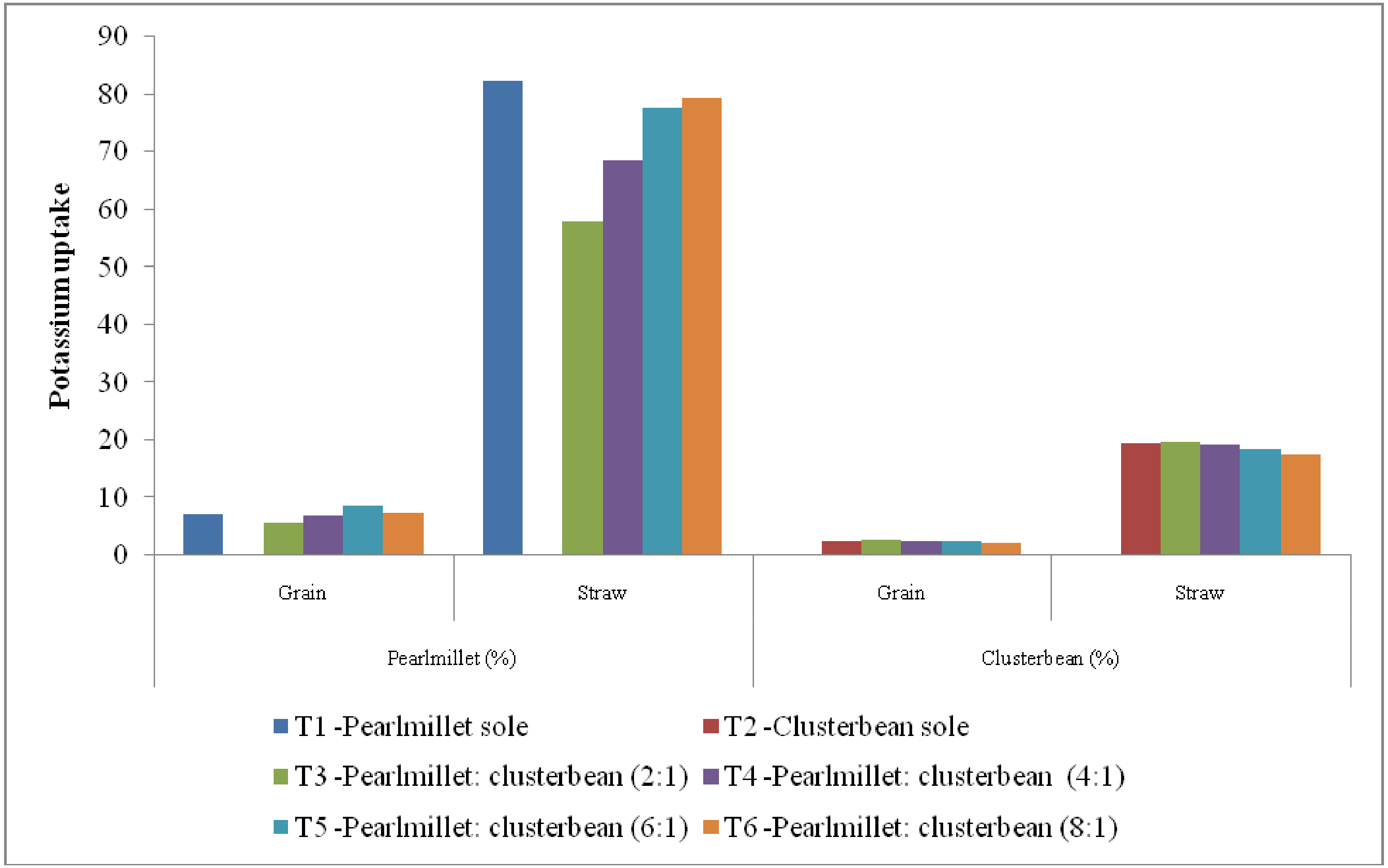
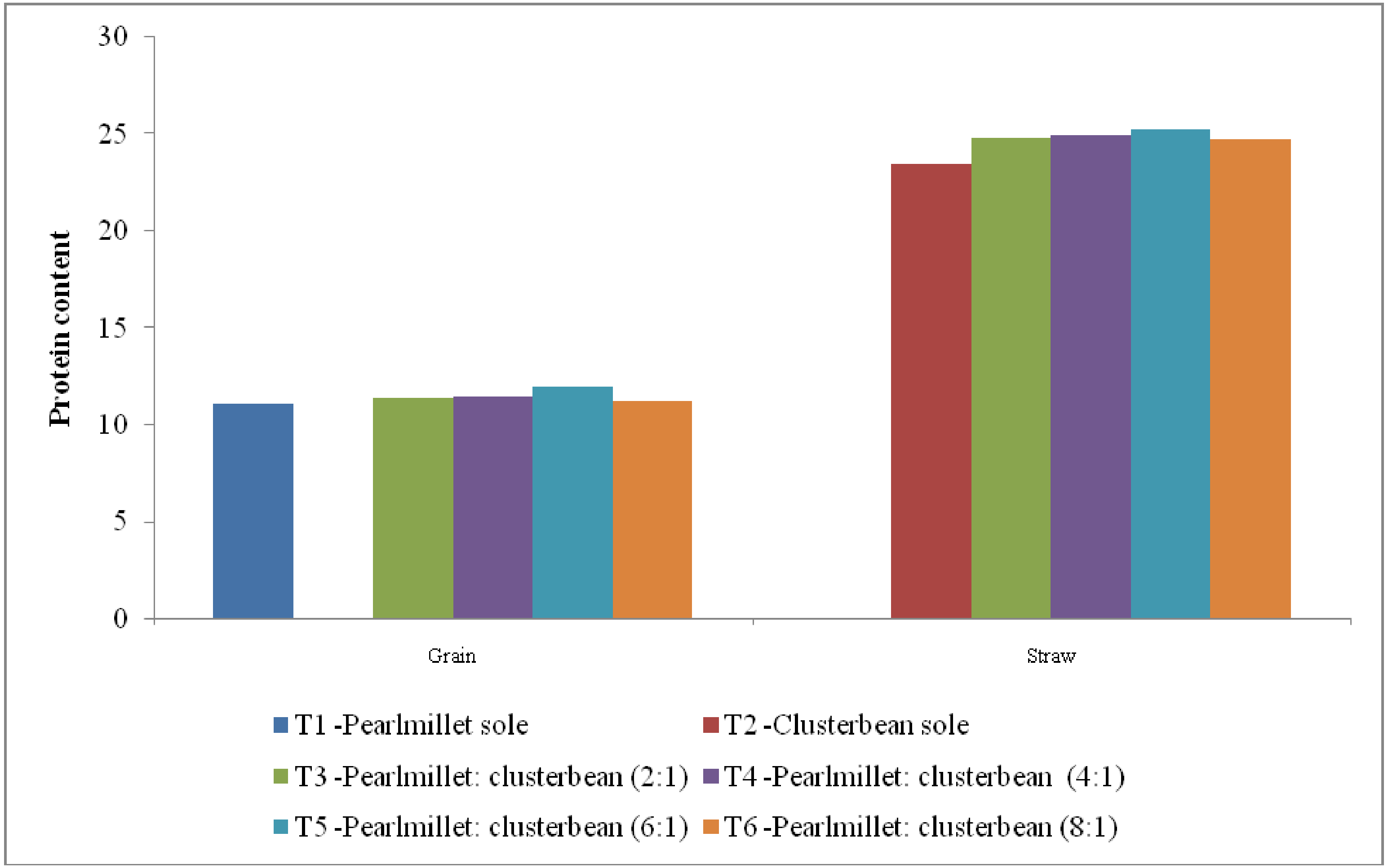


Figure 4.18 : Effect of planting pattern on protein content in pearl millet and cluster bean



DISCUSSION

The present investigation entitled **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of vindyan region"** conducted during *kharif* season of 2011 at Agricultural research farm of RGSC, BHU, Barkachha, are presented and described in this chapter. The experimental findings have been described in the preceding chapter; an attempt has been made to analyses the results critically in the light of causes of variation. The findings of earlier workers on the subject have also been taken in to consideration while discussing the result of present investigation. The discussion is presented under various heads.

The final yield of a crop is net result of the extent of successful completion of the growth and development activities in individual plant, which is in turn, would depend upon genetic potential of the cultivar and the environmental condition to which it is exposed during the course of life cycle.

5.1 WEATHER CONDITION DURING THE GROWING SEASON

Crop growth is mainly dependent on environmental factors. Fluctuations in weather conditions greatly influence growth, development and yielding potential of crop. The total rainfall during the crop season was 1080 mm. Though the rainfall was not well distributed, the amount of rainfall was sufficient to get good crop growth of pearl millet and cluster bean.

There was not much deviation in monthly maximum and minimum temperatures and relative humidity from the normal. In general, the normal growth and development of both the crops was observed.

5.2 EFFECT OF PLANTING PATTERN

5.2.1 Growth characters

When two or more crops are grown together as intercrops, their yields are generally reduced in planting pattern as compared to yields obtained under their sole cropping system, although combined yield may be higher than either of the sole crops. However, it is possible that the decrease in yields of component crops, when grown together could be minimized by selecting crops of different growth habits (Willey *et al.*, 1986). Pearl millet and cluster bean are two such crops which are morphologically and physiologically different in their growth habit.

Significant increase in plant height, number of leaves and number of tillers in pearl millet at 25, 50 and 75 DAS and at harvest observed under pearl millet: cluster bean (6:1) intercropping system (Table 4.1,4.2 and 4.3). However, greater dry matter production plant^{-1} of pearl millet at 50 and 75 DAS and at harvest (Table-4.4) was recorded under pearl millet: cluster bean (6:1) planting patter.

Significant increase in plant height and number of branches in cluster bean at 25, 50 and 75 DAS and at harvest observed under pearl millet: cluster bean (6:1) intercropping system (Table- 4.7 and 4.8). However, greater dry matter production plant^{-1} of cluster bean at 50 and 75 DAS and at harvest (Table-4.9) was recorded under pearl millet: cluster bean (6:1) intercropping. The increase in height may be attributed to more competition between cluster bean due to reduction in inter-row spacing from 40 to 10 cm and component crop for sunlight and others growth resources which compelled the plants to grow more pronounced. This might be due to the fact that legume intercrops were competitive with cluster bean for nutrients and environmental resources. Both the crops utilized the nutrients from the same fertilizer given to base crop under intercropping situation. On the other hand better growth and dry matter production in sole cluster bean might be the result of maximum utilization of nutrients and resources on account of competition free atmosphere available under sole cropping. Result showed that highest dry matter production per meter row length of cluster bean was observed under pearl millet: cluster bean (6:1) intercropping system (Table 4.9). This might be due to availability of more space, less competition for light, less shading effect and low inter-row competition as compared to other intercropping systems of pearl millet with cluster bean in different row ratios. Wider space in between rows and more rows of component legume crop provided better environment of the rhizosphere leads to significantly higher number of branches plant^{-1} in these treatments.

Anjeneyulu *et al.* (1982) reported that height of pearl millet was influenced marginally by intercropping system; however, higher dry matter production and leaf area index (LAI) were recorded in intercropping with cluster bean compared with sole cropping. While, Bangali (1987) working at Jobner observed that plant height, dry matter production and number of tillers per meter row length significantly increased under paired planting of pearl millet intercropped with cowpea and mung bean over sole pearl millet. Sharma (1997) similar result intercropping of cluster bean, cowpea and mung bean with pearl millet and reported that intercropping significantly enhanced plant height, dry matter accumulation and branches per plant of cluster bean, cowpea and mung bean at all the successive stages.

Khateek *et al.* (1999) reported that intercropping increased plant height of pearl millet. Ram *et al.,* (2003) observed that the maximum plant height of pearl millet was recorded under sole pearl millet being at par with pearl millet + cluster bean, significantly higher compared to pearl millet intercropped with cowpea and greengram. Yadav *et al.* (2005) reported similar results on growth parameter of cluster bean in intercropping system.

5.3 Yield and yield attributes:

The different intercropping system did not differ significant differences on number of grains ear^{-1}, test weight, ear length while significantly influenced the ear girth, ear weight. The higher values of these characters were recorded under pearl millet: cluster bean 6:1 (T_5) (Table 4.5, and 4.6, 4.10 and 4.11). The pearl millet: cluster bean 6:1 (T_5) system was at par with pearl millet: cluster bean 4:1 (T_4) in case of ear girth while all the treatments were statistically at par to each other in case of ear weight. Whereas, plant grain yield, straw yield, and biological yield were recorded pearl millet sole (4.6) as discussed earlier it might be due to the fact that legume intercrops were competitive with pearl millet for nutrients and environmental resources. Among the different systems the sole pearl millet was recorded significantly higher grain yield (1554.53 kg ha^{-1}) as well as straw yield (5104.11 kg ha^{-1}) over remaining intercropping system (Table 4.6). Seed and straw yields are largely a function of better growth and improvement in yield attributes which contribute to the seed and straw yields of the crop.

The different intercropping system had significantly influence on yield attributes of cluster bean *viz.,* Pod's parameter and pods $plant^{-1}$, no of cluster $plant^{-1}$, no of grains $pods^{-1}$ of these characters were recorded higher under pearl millet: cluster bean (6:1) (Table 4.10). The different intercropping system had significant influence on yield of cluster bean *viz.,* grain yield, straw yield, biological yield, were recorded significantly higher under sole cluster bean (Table 4.11). As discussed earlier it might be due to the fact that legume intercrops were competitive with cluster bean for nutrients and environmental resources. Seed and straw yields are largely a function of better growth and improvement in yield attributes which contribute to the seed and straw yields of the crop. Sharma and Gupta (2001) also reported decrease in the yield attributes, grain and straw yield of intercrops as compared to sole crop system.

Bangali (1987) observed that number of ear per meter row length increased significantly in paired pearl millet intercropped with cowpea over sole pearl millet but test weight, grain weight per ear and ear length remained unaffected. Tiwana and Tiwana (1995) at Bathinda (Punjab) found the highest total seed/grain yield in 3:1 cluster bean + pearl millet ratio. Singh and Joshi (1997) observed that row intercropping of pearl millet with cluster bean (1:1) and strip cropping (4:4) with 50 per cent of the sole pearl millet population produced 35.4 per cent lower pearl millet yield in the moisture season and 37.4 per cent lower pearl millet yield in the moisture stressed season. Pal *et al.* (2000) observed that the growth and yield attributes of pearl millet did not vary significantly due to intercropping treatments.

Ram *et al*. (2003) observed that the sole pearl millet gave significantly more ear length, grain per ear, grain (20.8 q ha^{-1}) straw (54.9 q ha^{-1}) and biological (75.6 q ha^{-1}) yield compared to rest of the intercropping systems, while highest pearl millet grain equivalent yield was recorded under pearl millet + cluster bean (39.1 q ha^{-1}) followed by pearl millet + greengram over pearl millet + cowpea and sole pearl millet. Singh and Agrawal (2004) observed that yield attributed (length of ear, grain weight/ear and 1,000-grain weight) of pearl millet were not influenced by intercropping system.

5.4 Quality of pearl millet and cluster bean

The data relating to the nitrogen, phosphorus and potassium content of pearl millet and cluster bean grain and straw have been presented in Table 4.12, 4.13 and 4.14. The maximum nitrogen content in pearl millet grain 1.71(%) and straw 0.62 (%) were observed under pearl millet: cluster bean (6:1). However, in cluster bean it was recorded under pearl millet: cluster bean (6:1) grain 4.04 and straw 0.97 respectively. The maximum phosphorus content in pearl millet grain 0.36 (%) were observed under (T_5), (T_3) and straw 0.20 (%) were observed under (T_6), (T_3) treatment. However in cluster bean the maximum phosphorus content in grain 0.31(%) and straw 0.11 (%) were observed under pearl millet: cluster bean 6:1 (T_5). The maximum potassium content in pearl millet grain 0.592 (%) and strew 1.641 in were observed pearl millet: cluster bean 6:1 (T_5) treatment. Whereas, in cluster bean the maximum potassium canton in grain 0.169 (%) and straw 0.620 (%) were observed under pearl millet: cluster bean 6:1(T_5).

The data relating to the nitrogen, phosphorus and potassium uptake of pearl millet and cluster bean grain and straw have been presented in Table 4.15, 4.16 and 4.17. The maximum nitrogen uptake by pearl millet grain 26.02 kg ha^{-1}, straw 30.20 kg ha^{-1} and total 56.22 kg ha^{-1} were observed under pearl millet sole (T_1). However, in cluster bean, the maximum nitrogen uptake by grain 62.62 kg ha^{-1}, straw 30.19 kg ha^{-1} and total 92.81 kg ha^{-1} were observed under pearl millet: cluster bean 2:1 (T_3). The maximum phosphorus uptake by pearl millet grain 5.43 kg ha^{-1}, straw 9.94 kg ha^{-1} and total 15.37 kg ha^{-1} were observed under pearl millet sole $(T)_1$. Whereas, in cluster bean the maximum phosphorus uptake by straw 3.48 kg ha^{-1} and total 7.83 kg ha^{-1} were observed under cluster bean sole (T_2), or in grain 4.59 kg ha^{-1} was observed under pearl millet: cluster bean (T_3). The maximum potassium uptake by pearl millet grain 8.53 kg ha^{-1} under pearl millet: cluster bean 6:1 (T_5) or straw 82.43 kg ha^{-1} and total 89.60 kg ha^{-1} were observed under pearl millet sole (T_1). Whereas, in cluster bean the maximum potassium uptake by grain 2.59 kg ha^{1}, straw 19.84 kg ha^{-1} and total 22.44 kg ha^{-1} were observed under (T_3) pearl millet: cluster bean (2:1).

The data relating to the protein content of pearl millet and cluster bean grain have been presented in Table 4.18. In intercropping treatment improved protein content in grain significantly. Pearl millet: cluster bean (6:1) recorded significantly higher grain protein content (11.94%) in pearl millet and cluster bean (25.23%). Sharma, *et al.* (2009) showed that pearl millet + cowpea (2:2) recorded significantly crude protein yield (1.36 t/ha). Hooda, *et al.* (2005) reported sole pearl millet recorded significantly the highest protein yield (125.1 and 123.33 kg/ha, respectively) than inter (2:1) and strip (4:2) and (6:3) cropping systems. Among the legumes, the highest protein content (10.31%) was recorded in strip-cropping of pearl millet with cowpea in 6:3 ratio. However, the highest protein yield was recorded in sole mung bean (119.27 kg/ha) and sole cluster bean (73.70 kg/ha) during the first and second year, respectively.

Bangali (1987) reported that nitrogen and protein content of pearl millet grain and straw increased significantly under paired pearl millet intercropped with cowpea and mung bean compared to sole crop further, total nitrogen, & phosphorus uptake by pearl millet were significantly influenced due to intercropping system. Singh *et al.,* (1989) reported that the intercropping increased grain protein content and nitrogen uptake in pearl millet when intercropped with cluster bean.

Singh (1992) observed that nitrogen uptake by grain and straw and total uptake was maximum in pearl millet + cluster bean intercropping as compared to pearl millet: mung bean and pure stand of pearl millet. Ikramullah *et al.* (1996) reported that nitrogen uptake by sorghum crop was significantly more in the sole sorghum than intercropping systems.

5.5 Indices

Data presented in Table 4.19 indicated that intercropping treatments significantly influenced the pearl millet grain equivalent yield. The maximum mean pearl millet grain equivalent yield (4767.24 kg ha^{-1}) was obtained under pearl millet sole significantly higher than all other treatments. Land equivalent ratio (LER) implies the relative land area under sole crops that is required to produce the yields achieved in intercropping under same level of management (Willey, 1979).

The obvious reason for large yield advantage in intercropping system is that the component crops differed in their use of natural resources and utilized them more efficiently resulting in higher yields per unit area than that produced by their sole crops. Cluster bean being short duration crop with slow initial growth and deep root system did not pose any severe competition for natural resources with pearl millet under different row proportions.

The land equivalent ratio treatments were significantly higher than sole pearl millet. Among the intercropping treatments, row ratio have pearl millet: cluster bean (4:1) maximum LER 2.12 followed by 2.07 under row ratio pearl millet: cluster bean (6:1).

Rathore, *et al.* (2006) result found cluster bean was more suitable for intercropping in pearl millet as it gave higher mean pearl millet equivalent yield (1351 kg/ha), LER (1.01) and gross monetary returns (Rs. 7454/ha). Intercropping system 2:4 (pearl millet: legume) recorded higher pearl millet equivalent yield, LER and gross monetary returns. Moth bean can only be sown with a 2:4 row ratio.

Singh (1994) conducted an experiment in arid zone at Mandor- Jodhpur and reported that 4:4 ratio of pearl millet + moth bean gave significantly higher land equivalent ratio (LER) and net return as compare to sole pearl millet and 4:3, 4:2 row ratio.

Patel *et al,* (1998) observed that on the basis of net realization, CBR and LER, pearl millet intercropped with cluster bean with a row ratio of 2:1 was superior among different intercropped treatments.

Aher *et al*. (1996) reported that pearl millet + moth bean intercrop produced the highest seed yield, land equivalent ratio (1.32) and the highest gross returns.

Yadav and Yadav (2000) reported that pearl millet + cluster bean mixed in 1:2 ratio gave the highest land equivalent ratio as compare to all other treatments.

5.6 Economics

Data presented in Table 4.20 showed that intercropping treatment has maximum net returns (Rs. 48,441 ha^{-1}). The maximum net return per rupee investment was obtained in (Rs. 32,900) pearl millet: cluster bean 4:1 closely followed by pearl millet: cluster bean (6:1) row cropping of pearl millet and cluster bean. The maximum B:C ratio 2.47 under pearl millet: cluster bean 6:1.

Sharma *et al.* (2009) showed that pearl millet + cow pea (2:2) recorded significantly s net returns (Rs 24,060/ha) compared with the other treatments. The highest land-equivalent ratio (1.42), relative crowding coefficient (6.54) and lowest value of competitive ratio (1.29) also indicated superiority of pearl millet + cowpea system. Among the component crops, pearl millet was more competitive and aggressive to legume intercrops. However, maximum Aggresivity index (0.55) and competitive ratio (3.42) were obtained with pearl millet: cluster bean (1:2). Thus, intercropping of pearl millet and cowpea in 2:2 row ratios may be adopted for higher fodder productivity, quality and profitability during summer.

Rao *et al.* (2009) observed that intercropping of sorghum with mung bean in 2:1 row ratio at 50 kg N/ha recorded the highest land equivalent ratio, price equivalent ratio (1.23), relative crowding co-efficient (10.99), net returns (Rs. 14857/ha) and benefit : cost ratio (2.64).

Chapter-VI

SUMMARY AND CONCLUSION

The present investigation entitled on **"Effect of planting pattern on growth, yield and quality of pearl millet (*Pennisetum glaucum* L.) + cluster bean (*Cyamopsis tetragonoloba* L.) intercropping under agri-horti system of Vindyan region"** conducted during *Kharif* season of 2011 at Agricultural research farm of RGSC, BHU, Barkachha, are presented and described in this chapter. The maximum plant height pearl millet crop 66.72, 126.45, 197.83 and 205.23 cm at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5) intercropping. The maximum leaves plant^{-1} pearl millet crop 10.40, 16.58, 26.44 and 26.64 cm at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5). The maximum number of tillers plant^{-1} 2.03, 2.70, 3.29 and 3.37 at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5) intercropping. The maximum dry matter accumulation plant^{-1} 7.48, 57.96, 115.40 and 134.86 g at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5) intercropping. The maximum no. of grains ear^{-1}, ear girth (cm), ear length (cm) and weight of ear were observed as 1416.75, 10.55 cm, 23.82 cm and 24.75 g under Pearl millet: cluster bean 6:1 (T_5) intercropping. The maximum test weight 9.89 g was observed under Pearl millet: cluster bean 6:1 (T_5) in intercropping. The maximum grain yield 1554.53 kg ha^{-1} recorded under (T_1) pearl millet sole was significantly higher over rest of the treatments. The maximum straw yield 5104.11 kg ha^{-1} recorded under pearl millet sole (T_1) was significantly superior over rest of the treatments. The maximum biological yield 6658.64 kg ha^{-1} recorded under pearl millet sole (T_1) was significantly superior over rest of the treatments. The highest value of harvest index was recorded under Pearl millet: cluster bean 4:1 (T_4) 23.47 (%) in intercropping.

The maximum plant height of cluster bean 27.38, 85.49, 114.90 and 118.73 cm at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5) intercropping, respectively. The maximum number of branches plant^{-1} 1.74, 3.72, 4.61 and 4.62 at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5). The maximum dry matter accumulation plant^{-1} 2.27, 11.59, 24.89 and 27.83 gram at 25, 50, 75 DAS and harvest was observed under Pearl millet: cluster bean 6:1 (T_5) intercropping. The maximum number of clusters plant^{-1}, number of pod plant^{-1}, number of grain pod^{-1} and test weight (g) were observed as 8.94, 34.05, 7.69 and 31.97 under Pearl millet: cluster bean 6:1 (T_5), respectively in intercropping. The maximum grain yield 1606.67 kg ha^{-1} recorded under cluster bean sole (T_1) was significantly higher over rest of the treatments. The maximum straw yield 3312.44 kg ha^{-1} recorded under cluster bean sole (T_1) was significantly superior over rest of the treatments. The maximum biological yield of 4919.11 kg ha^{-1} which was significantly higher cluster bean sole (T_1) over all other intercropping patterns. The highest value of harvest index was recorded under Pearl millet: cluster bean 2:1 (T_3) 32.80 percent significantly superior over rest of the treatments.

The maximum nitrogen content in pearl millet grain 1.71(%) and straw 0.62 (%) under pearl millet: cluster bean 6:1 (T_5) respectively in intercropping. The maximum nitrogen content in cluster bean grain 4.04 (%) and straw 0.95 (%) under pearl millet: cluster bean 6:1 (T_5) respectively in intercropping. The maximum phosphorus content in pearl millet grain 0.36 (%) under pearl millet: cluster bean 6:1 (T_5) and straw 0.20 (%) under pearl millet: cluster bean (T_6) and (T_3) treatment respectively in intercropping. The maximum phosphorus content in cluster bean grain 0.31 (%) and straw 0.11 (%) under pearl millet: cluster bean 6:1 (T_5) respectively in intercropping. The maximum potassium content in pearl millet grain 0.592 (%) and straw 1.641(%) under pearl millet: cluster bean 6:1 (T_6) respectively in intercropping. The maximum potassium content in cluster bean grain 0.169 (%) and straw 0.620 (%) were observed under pearl millet: cluster bean 6:1 (T_5) in treatment.

The maximum nitrogen uptake by pearl millet grain 26.02 kg, straw 30.20 kg and total 56.22 kg under pearl millet sole (T_1) respectively in intercropping. The maximum nitrogen uptake by cluster bean grain 62.62 kg, straw 30.19 kg and total 92.81 kg under pearl millet: cluster bean 2:1 (T_3), respectively in intercropping. The maximum phosphorus uptake by pearl millet grain 5.43 kg, straw 9.94 kg and total 15.37 kg under pearl millet sole (T_1) respectively in intercropping. The maximum phosphorus uptake by cluster bean grain 4.59 kg grain under Pearl millet: cluster bean

2:1 (T_3), and straw 3.48 kg or total 7.83 kg were observed under cluster bean sole (T_2) in treatment. The maximum potassium uptake in pearl millet grain 8.53 kg under (T_6) pearl millet: cluster bean (6:1) and straw 82.43 kg and total 89.60 kg under pearl millet sole (T_1) respectively in intercropping. The maximum potassium uptake in cluster bean grain 2.59 kg, straw 19.84 kg and total 22.44 kg were observed under pearl millet: cluster bean 2:1 (T_3) respectively in intercropping.

The maximum protein content in pearl millet grain 11.94 (%) was observed under pearl millet: cluster bean 6:1 (T_5) respectively in intercropping. The maximum protein content in cluster bean grain 25.23 (%) was observed under pearl millet: cluster bean 6:1 (T_5) in treatment

The maximum mean pearl millet grain equivalent yield (4767.24 kg ha^{-1}) was obtained under (T_1) pearl millet sole significantly higher than all other treatments. The maximum mean pearl millet land equivalent ratio (2.12) was obtained under (T_5) pearl millet: mung bean (6:1), significantly higher than all other treatments.

The maximum net returns (Rs. 48441 ha^{-1}) was observed under pearl millet: cluster bean 6:1 (T_5). The maximum B:C ratios (2.47) was observed under pearl millet :cluster bean 6:1 (T_5) in comparison to all intercropping treatments.

Conclusion:

Based on experimental finding the following conclusion may be drawn;

1. Intercropping in planting pattern pearl millet: cluster bean 6:1 (T_5) proportion provides higher growth attributes yield attributes, pearl millet equivalent yield (kg ha^{-1}) in agri-horti system
2. Maximum nutrient content of N, P and K pearl millet: cluster bean 6:1 (T_5) in planting pattern intercrop followed by pearl millet: cluster bean 4:1(T_4) row ratio treatment from the rest of other.
3. Maximum *utilization* of N, P and K nutrient uptake by the pearl millet sole and cluster bean in planting pattern intercrop followed by pearl millet: cluster bean (8:1) row ratio treatment from the rest of other.

4. The maximum LER value was recorded under pearl millet: cluster bean (6:1) planting pattern

5. Maximum Net return Rs. 48441 was with pearl millet: cluster bean 6:1 (T_5) treatment were has B:C ratio (2.47) was observed pearl millet: cluster bean 6:1 (T_5) row ratio treatment in agri-horti system in Vindyan region.

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