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Growth and Yield Response of Soybean and Maize to Sunhemp Green Manuring and Intercropping in a Vertisol

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ABSTRACT

Present investigation was carried out at the Research Farm of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), College of Agriculture, Indore during kharif 2017. The experiment was laid out in a randomized block design (RBD) replicated thrice with eight different treatments involving combinations of green manuring and intercropping of sunhemp, soybean and maize crops. Soybean (JS 95-60) and Maize (K 604 hybrid) were grown as rainfed crops in Kharif 2017 with 20:60:40 and 120:60:40 kg ha^{-1} recommended dose of N:P_2O_5: K_2O fertilizers, respectively with Sunhemp as a green manure crop. The response of soybean and maize crops in terms of growth and yield attributes and yield was studied. The results revealed that the growth and growth attributes of soybean and maize were found higher under the incorporation of green manuring and soybean + maize intercrop. The green manuring and intercropping enhanced plant height, branching, nodulation, pods per plant and seeds per pod in soybean by 7-11%, 11-34%, 9-18%, 33% and 7-12% higher, respectively over the sole soybean. Similarly, the grains per cob in maize was found 20-23% higher under green manuring while it was 20% higher under maize+soybean intercropping. The seed yield of soybean was found decreased by 7-17% and 45% under green manuring and maize intercropping, respectively. However, the maize grain yield showed 3-5% increment under green manuring while it was reduced by 48% in intercropping. The data on Economic analysis showed highest net returns of Rs. 21581 Rs ha^{-1} and benefit: cost ratio of 2.25 under green manuring/intercropping.

Key words: *Sunhemp, Green manure, Intercrop, Soybean, Maize, Yield.*

INTRODUCTION

Green manure refers to fresh plant matter, which is added to the soil largely for supplying nutrients contained in the biomass. Such biomass can be either grown in situ and incorporated or grown elsewhere and brought in for incorporation in the field to be manured. The process is termed as green manuring. Green manuring is one of the ancient and most efficient practices of nutrient management, which is a cheap alternative to the use of nitrogen fertilizer.

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Green manuring with leguminous crops has been found to accumulate significant N and add good amount of nutrients to the soil especially nitrogen[1]. Leguminous plants are largely used for green manuring due to their N_2-fixing ability, drought tolerance, quick growth and adaption to adverse conditions**.** Green manuring is a low cost-effective technology useful in minimizing investment cost on fertilizer and other inputs, thus safeguarding the productive capacity of soil without impoverishment. A significant beneficial effect of green manures is mainly attributed to their rapid growth, nitrogen fixation, greater biomass accumulation, nutrient conservation in their green tissues and mineralization of the nutrients allowing increase in the uptake of nutrients by crops. Green manure crops ensure ecological sustainability by maintaining the productivity of the soil over a long period thus protecting soil from erosion. Incorporation of under sown legumes returned 93–177 kg N, 16–20 kg P_2O_5 and 98– 153 kg K_2O ha^{-1} to soil[2]. Addition of organic matter through green manures plays an important role in improving productivity of crop besides improvement in soil physico-chemical properties, which often deteriorate under intensive cropping involving inorganic fertilization[3].

Soybean [*Glycine max* (L.) Merrill] is an important leguminous and oilseed crop of India which contains 40% protein and 20% oil. Soybean occupies an area of 110.65 lakh ha which yields 83.42 lakh mt productions with an average productivity of 1.28 mt ha^{-1} in the country. The state of Madhya Pradesh ranks first in soybean production followed by Maharashtra, Rajasthan, Andhra Pradesh and Karnataka[4]. The Area, production and productivity of soybean in Madhya Pradesh are 5.401 million ha, 5.717 million tonnes, and 784 kg ha^{-1} respectively[4]. Similarly, the Maize (*zea mays L.*) popularly known as "corn" is also one of the most important cereals next to wheat and rice in the world's agriculture economy both as food for human being and feed for animals. In term of world ranking, maize stands third among the food crop, next to rice and wheat, both in the respect of area and production. Maize is different from other cereals due to its higher yield potential than any other cereals. But now days the farmers are facing problems in growing soybean due to heavy production cost, frequent diseases and pest attack, low productivity and adverse climate conditions. These problems can be addressed by adopting the green manuring and intercropping techniques. Intercropping is the practice of growing more than one crop simultaneously in alternating rows of the same field[5,8]. It is an effective practice in maize production which not only helps in reducing the available space for weed growth but also increases the production per unit area. The beneficial effects of the green manuring and intercropping have already been studied in various part of the world in different soils and diverse crops[9,11] but the information is lacking in a vertisol especially under soybean-maize intercrop with sunhemp as a green manuring crop. Hence, a field experiment was conducted to evaluate the effect of green manure and intercropping on growth and yield response of soybean and maize crops.

MATERIAL AND METHODS

The field experiment was conducted during the *kharif* season of the year 2017-18 at the research farm of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), College of Agriculture, Indore. The experimental site has almost uniform topography with light to medium black soils. Indore is situated in Malwa Plateau in western parts of Madhya Pradesh on 22.43° N and 75.66° E with an altitude of 556 meters above the mean sea level.

The study area is situated in semi-arid tropics of Malwa Plateau in Madhya Pradesh state of central India having hot moist climate. Summers are dry with the rising temperature up to 44°C or even higher during April-May. The winters are normal with temperature descending up to 10°C or even more during December and January. The average annual rainfall varies from 750 mm to 1000 mm and 90 % of this is received during the last week of

June, July, August, September and first week of October through South-West monsoon. The meteorological data viz. temperature, relative humidity and rainfall recorded at the meteorological observatory located at AICRPDA; Indore during the cropping season is presented in Fig 1.

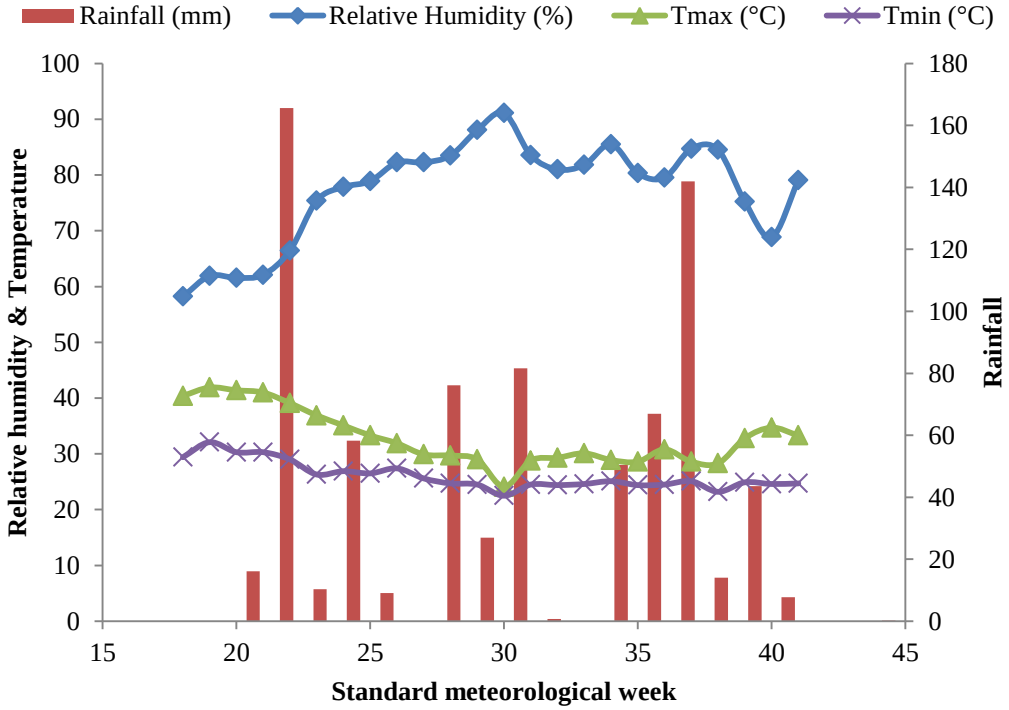

Figure 1. Weekly weather data during crop growth period

The field experiment was carried out with 8 treatments replicated thrice in a Randomized Block Design (RBD). The treatments involved T_1 (Soybean + sunhemp (2:1) at 30 cm); T_2 (Soybean + sunhemp (1:1) at 45 cm); T_3 (Sole soybean at 45 cm); T_4 (Maize + Sunhemp (2:1) at 45 cm); T_5 (Maize + Sunhemp (1:1) at 30 cm); T_6 (Sole Maize at 60 cm); T_7 (Soybean + Maize (1:1) at 45 cm); T_8 (Sole sunhemp at 30 cm). The details of treatments and field experiment are given in Table 1. The green manurung crop sunhemp, soybean (cv. JS 95-60) and maize (cv. K 604 Hybrid) were sown in the last week of June. The soybean and maize were grown with 20:60:40 and 120:60:40 kg ha-1 recommended dose of N: P_2O_5:K_2O, respectively. The sunhemp was incorporated in the first week of August. Similarly, the soybean and maize crops were harvested in first week of October and November, respectively at maturity (Table 2).

Table 1. Detail of Treatments

Treatment	Description
T_1	Soybean + sunhemp (2:1) at 30 cm
T_2	Soybean + sunhemp (1:1) at 45 cm
T_3	Sole soybean at 45 cm
T_4	Maize + Sunhemp (2:1) at 45 cm
T_5	Maize + Sunhemp (1:1) at 30 cm
T_6	Sole Maize at 60 cm
T_7	Soybean + Maize (1:1) at 45 cm
T_8	Sole sunhemp at 30 cm

In order to get a good tilth of soil for sowing, the experimental field was given one ploughing. The field was leveled before sowing. Soybean seed @ 80 kg ha^{-1} and maize seed @ 25 kg ha^{-1} were sown at row to row and plant to plant spacing according to decided treatments. The recommended doses of fertilizers for soybean and maize were applied in all the treatments as basal dose at the time of sowing. The green manure crop sunhemp was grown and incorporated in the soil after 40 DAS in the treatments involving its application.

Table 2. Detail of experiment

Particular	Detail
No. of treatment	8
Replication	3
Design	Randomized Block Design (RBD)
Crop (Cultivar)	Soybean (JS 95-60); Maize (K 604 hybrid)
Seed Rate (kg ha^{-1})	80 (Soybean); 25 (Maize); 15-20 (Sunhemp)
Dose of fertilizer (kg ha^{-1}) N: P_2O_5:K_2O	20:60:40 (Soybean); 120:60:40 (Maize)
Date of sowing	29/06/2017
Date of green manure incorporation	05/08/2017
Date of Harvesting	06/10/2017 (Soybean); 01/11/2017 (Maize)

Field Observations:

The influence of different treatments on soybean and maize, observations with respect to the growth parameters and yield attributing characters of crop were recorded. Three plants were randomly selected in each plot and tagged with labels for various observations on growth parameters and yield attributes. Plant height of soybean and maize was measured in order to estimate the effect and extent of plant growth due to various treatments. Height of the three randomly selected plants in each plot was measured. Height was measured in cm from the soil surface to the main stem (apical). The number of branches per soybean plant was counted from randomly selected three plants in each plot. The number of root nodules of three randomly selected soybean plants was recorded in each plot. Soybean plants were uprooted carefully, washed and root nodules were separated, counted and recorded. At physiological maturity the crops were harvested and observations were recorded and computed. The pods from the tagged soybean plants were counted and thus obtained mean was used for statistical analysis. Randomly selected pods of soybean plant from each plot were threshed and numbers of seed were counted and divided by pod number to obtain the seeds per pod. The cobs from the randomly selected maize plants were counted and thus obtained mean was used for statistical analysis. Randomly selected cobs of maize from each plot were threshed; numbers of grains were counted and expressed as grains per cob.

Yield and Seed Index

The harvested produce from each plot was tied in bundles separately, sun dried and bundle weight (biological yield) was recorded with the help of spring balance. The weight of cleaned grains obtained from each net plot after threshing and thereafter converted into kilograms per hectare by using appropriate factor. Straw yield was calculated for each net plot by subtracting the grain yield from the bundle weight of the respective plot. Random seed and grain samples of soybean and maize were taken from each treatment and hundred seeds were counted. The counted seeds/grains were weighed accurately on electronic balance and expressed in grams.

Soybean equivalent yield (SEY)

Crop (Soybean) equivalent yield was calculated by the following formula.

$$Soybean\ equivalent\ yield\ (SEY) = \frac{Yield\ of\ maize\ (kg/ha) \times Market\ price\ (Rs./kg)}{Market\ price\ of\ soybean\ (Rs./kg)}$$

Economics

The economics of each treatment was calculated as per existing market prices by method described by Tandon and Dhodyal[12]. Cost of cultivation was worked out from the summation of cost of expenditure incurred on preparation of experimental field, sowing, weeding operations, inputs applied, harvesting, daily wages, etc. in Rs. $ha^{-1.}$ The gross returns in terms of Rs. ha^{-1} was worked out for each treatment taking the present market cost of seed cotton yield and stalk yield. Net Monetary Returns was obtained by subtracting cost of cultivation from gross returns. It is good indicator of suitability of cropping system/treatments since this represents the actual income of the farmer. Monetary returns for different treatments were calculated with the help of prevailing market rates of output and inputs. Benefit: cost ratio (B: C) is the ratio of gross return to cost of cultivation. It is expressed as returns per rupee invested.

$$Benefit : cost\ ratio\ (B:C) = \frac{Gross\ monetary\ returns}{Total\ cost\ of\ cultivation}$$

The data obtained on various parameters were tabulated and subjected to statistical analysis. Since for drawing valid information regarding treatment, the degree of freedom for any design should not be less than 12. In the present study regarding individual crop growth character etc. The error degree of freedom is only six, therefore the result of individual crop was interpreted on the basis of mean as well as percentage increment over the treatments.

RESULTS AND DISCUSSION

Growth and yield attributes of soybean and maize

Plant population and plant height

The plant population of soybean was ranged from 14.53 to 17.63 plants per meter row length (plants m^{-1} row length) under different treatment combinations (Table 3). The highest plant population of soybean was observed under the treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) followed by treatment T_7 (Soybean + Maize (1:1) at 45 cm) whereas the lowest plant population of soybean was recorded in the treatment involving sole soybean crop maintained with row to row spacing of 45 cm. The plant height of soybean recorded at the harvest of the crop was ranged between 46.84 cm and 52.30 cm (Table 3). The plant height of soybean followed following trend among different treatments: $T_2>T_1>T_7>T_3$. The treatment T_2 (Soybean + sunhemp (1:1) at 45 cm) showed highest plant height of soybean as compared to the other treatments followed by the treatment T_1 (Soybean + sunhemp (2:1) at 30 cm). The treatment T_3 (Sole soybean at 45 cm) showed lowest height of soybean plant (Table 3).

The plant population of maize was ranged from 5.60 to 6.47 plants per meter row length (plants m^{-1} row length) under different treatment combinations (Table 3). The highest plant population of maize was observed under the treatment T_7 (Soybean + Maize (1:1) at 45 cm) followed by treatment T_5 (Maize + Sunhemp (1:1) at 30 cm) whereas the lowest plant population of maize was recorded in the treatment involving sole maize crop maintained with row to row spacing of 60 cm. The plant height of maize recorded at the harvest of the crop was ranged between 167.63 cm and 174.74 cm (Table 3). The plant height of maize followed following trend among different treatments: $T_5>T_7>T_4>T_6$. The treatment T_5 (Maize + Sunhemp (1:1) at 30 cm) showed highest plant height of maize as compared to the other treatments followed by the treatment T_7 (Soybean + Maize (1:1) at 45 cm). The treatment T_6 (Sole Maize at 60 cm) showed lowest height of maize plant (Table 3).

Table 3. Growth and yield attributes of soybean and maize influenced by green manuring and intercropping

Treatment	Soybean				Maize			
	Plant m^{-1} row length	Plant height (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	Plant m^{-1} row length	Plant height (cm)	Cobs $plant^{-1}$	Grains cob^{-1}
T_1	17.63	50.12	27.8	2.6	-	-	-	-
T_2	16.55	52.3	23.7	2.5	-	-	-	-
T_3	14.53	46.84	20.94	2.33	-	-	-	-
T_4	-	-	-	-	6.2	170.38	2.16	472.2
T_5	-	-	-	-	6.23	174.74	1.6	462.3
T_6	-	-	-	-	5.6	167.63	1.38	383.8
T_7	16.8	48.24	25.48	2.53	6.47	171.07	1.69	436.5
T_8	-	-	-	-	-	-	-	-

T_1-Soybean + sunhemp (2:1) at 30 cm; T_2-Soybean + sunhemp (1:1) at 45 cm; T_3-Sole soybean at 45 cm; T_4-Maize + Sunhemp (2:1) at 45 cm; T_5-Maize + Sunhemp (1:1) at 30 cm; T_6-Sole Maize at 60 cm; T_7-Soybean + Maize (1:1) at 45 cm; T_8-Sole sunhemp at 30 cm.

Number of pods per plant in soybean

The number of pods per plant in soybean varied from 20.94 to 27.80 among various treatments under study. The highest number of pods per plant was recorded in treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) followed by T_7 (Soybean + Maize (1:1) at 45 cm). The lowest number of pods in soybean was recorded for treatment T_3 in which sole soybean was grown with 45 cm row to row spacing (Table 3).

Number of seeds per pod in soybean

The number of seeds per pod in soybean varied between 2.33 and 2.60 among various treatments combinations. The treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) showed highest number of seeds per pod (2.60 seeds pod^{-1}) followed by T_7 (Soybean + Maize (1:1) at 45 cm). The lowest number of pods in soybean was recorded for treatment T_3 (Sole soybean at 45 cm). The number of seeds per pod in soybean followed the similar trend as that of number of pods per plant in soybean. The number of pods per plant and number of seeds per pod in soybean followed the trend: $T_1>T_7>T_2>T_3$ (Table 3).

Number of branches per plant in soybean

The data pertaining to the number of branches per plant in soybean has been presented in Table 4. The data revealed that, the number of branches per plant in soybean ranged from 1.89 to 2.53 among various treatments. The highest number of branches per plant in soybean was recorded in treatment T_2 (Soybean + sunhemp (1:1) at 45 cm followed by T_1 (Soybean + sunhemp (2:1) at 30 cm) (2.30 branches $plant^{-1}$). The lowest number of branches per plant was recorded under the treatment T_3 in which sole soybean crop was grown at 45 cm row to row spacing.

Number of nodules per plant in soybean

The number of nodules per plant in soybean at 45 DAS followed the trend: $T_1>T_2>T_7>T_3$. The number of nodules per plant ranged between 39 and 46.23 among different treatments under study. The highest number of nodules was recorded under the treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) followed by T_2 (Soybean + Sunhemp (1:1 at 45 cm). The lowest number of nodules was recorded under the treatment T_3 (Sole soybean at 45 cm). (Table 4).

Table4. Nodulation, branching and test weight as influenced by green manuring and intercropping

Treatment	Nodules $plant^{-1}$ in soybean	Branches $plant^{-1}$ in soybean	Test weight (g/100 seed)	
			Soybean	Maize
T_1	46.23	2.30	11.37	---
T_2	42.56	2.53	9.67	---
T_3	39.00	1.89	8.67	---
T_4	-	-	---	26.30
T_5	-	-	---	25.33
T_6	-	-	---	23.57
T_7	40.12	2.10	10.47	24.37
T_8	-	-	---	---

T_1-Soybean + sunhemp (2:1) at 30 cm; T_2-Soybean + sunhemp (1:1) at 45 cm; T_3-Sole soybean at 45 cm; T_4-Maize + Sunhemp (2:1) at 45 cm; T_5-Maize + Sunhemp (1:1) at 30 cm; T_6-Sole Maize at 60 cm; T_7-Soybean + Maize (1:1) at 45 cm; T_8-Sole sunhemp at 30 cm.

Test weight of soybean

The test weight of soybean was ranged from 8.67 to 11.37 g/100 seeds under different treatment combinations (Table 4). The highest test weight of soybean was observed under the treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) followed by treatment T_7 (Soybean + Maize (1:1) at 45 cm) whereas the lowest test weight of soybean was recorded in the treatment involving sole soybean crop maintained with row to row spacing of 45 cm (T_3). The test weight of soybean followed following trend among different treatments: $T_1>T_7>T_2>T_3$ (Table 4).

Number of cobs per plant in maize

The number of cobs per plant in maize varied from 1.38 to 2.16 among various treatments under study. The highest number of cobs per plant was recorded in treatment T_4 (Maize + Sunhemp (2:1) at 45 cm) followed by T_7 (Soybean + Maize (1:1) at 45 cm). The lowest number of cobs in maize was recorded for treatment T_6 in which sole maize was grown with 60 cm row to row spacing. (Table 3).

Number of grains per cob in maize

The number of grains per cob in maize varied between 383.80 and 472.20 among various treatments combinations. The treatment T_4 (Maize + Sunhemp (2:1) at 45 cm) showed highest number of grains per cob (472.20 grains cob^{-1}) followed by T_7 (Soybean + Maize (1:1) at 45 cm) (462.33 grains cob^{-1}). The lowest number of pods in soybean was recorded for treatment T_3 (Sole soybean at 45 cm). The number of grains per cob in maize followed the similar trend as that of number of cobs per plant in maize. The number of cobs per plant and number of grains per cob in maize followed the trend: $T_4>T_7>T_5>T_6$ (Table 3).

Test weight of maize

The test weight of maize recorded at the harvest of the crop was ranged between 23.57 and 26.30 g/100 seed (Table 4). The test weight of maize followed following trend among different treatments: $T_4>T_5>T_7>T_6$. The treatment T_4 (Maize + Sunhemp (2:1) at 45 cm) showed highest test weight of maize as compared to the other treatments followed by the treatment T_5 (Maize + Sunhemp (1:1) at 30 cm). The treatment T_6 (Sole Maize at 60 cm) showed lowest test weight of maize plant (Table 4).

The data revealed that the growth parameter like plant height of soybean was found to be 7-11% higher under green manuring whereas 7% higher under intercropping treatments as compared to the sole soybean cultivation. Similarly, the number of branches was also found to be 11-34% higher under green manuring and intercropping over the sole soybean. Thobatsi[13] also found significantly higher plant height under green manure intercropping as compared to the sole cropping. Premi *et al.*[14] found 11.1% higher branching in mustard under sesbania green manure intercropping. The results of the present study are in conformity with these findings. The yield attributes such as pods per plant and seeds per pod were found to be 13-33% and 7-12% higher, respectively in plots with in-situ incorporation of green manure and soybean grown with maize as intercrop. The green manuring and intercropping also had a positive effect on the nodulation in soybean. These treatments recorded 9-18% higher nodulation in soybean as compared to the sole soybean (Table 4). Similarly, the test weight of soybean was also found 12-31% and 0-9% higher in plots with in-situ incorporation of green manure and soybean grown with maize as intercrop, respectively. Legwiala *et al.*[15] also observed significant effect of green manuring and intercropping on yield attributes of cowpea such as numbers of flower per plant, number of seeds per pod and weight of seeds. The plant height of maize was not much influenced by the intercropping and green manuring treatments as the increment was only marginal (2-4% higher than sole maize) but the effect reflected in terms of grains per cob. The grains per cob in maize was found to be 14-23% higher under green manuring while it was 20% higher under maize+soybean intercropping. Similarly, the test weight of maize was also found to be 3-12% and 0-8% higher in plots with in-situ incorporation of green manure and soybean grown with maize

as intercrop, respectively. Singh *et al.*[16] observed that intercropping of maize with vegetable pea and lentil increased yield attributes *viz.*, length and girth of cob, number and weight of grains per cob and 1000 grain weight. Okpara *et al.*[17] also found significantly higher number of grains per cob in maize. The maximum plant height recorded under above mentioned treatments were mainly due to higher crop-intercrop competition *i.e*. plant attained height owing to less utilization of light and solar radiation.

Crop yield

Seed and straw yield of soybean

The seed yield of soybean ranged from 549 kg ha^{-1} in treatment T_7 (Soybean + Maize (1:1) at 45 cm) to 990 kg ha^{-1} in the treatment T_3 (Sole soybean at 45 cm). The lowest seed yield of soybean was recorded in treatment T_7. The treatment T_1 (Soybean + sunhemp (2:1) at 30 cm) and treatment T_2 (Soybean + sunhemp (1:1) at 45 cm) recorded soybean seed yield of 916 and 824 kg ha^{-1}, respectively (Table 5). Similarly, the straw yield of soybean varied between 1350 and 2460 kg ha^{-1} among different treatments under study and followed the trend: $T_3>T_1>T_2>T_7$. The straw yield of soybean was found to be higher under treatment T_3 (Sole soybean at 45 cm) followed by T_1 (2340 kg ha^{-1}). The treatment in which the soybean and maize grown as intercropping at a spacing of 45 cm i.e. T_7 showed lowest straw yield (1350 kg ha^{-1}) whereas, the treatment T_2 recorded higher straw biomass of 2130 kg ha^{-1} than T_7 (Table 5).

Table 5. Effect of green manuring and intercropping on yield of soybean and maize crops

Treatment	Soybean		Maize	
	Seed yield	Straw yield	Grain yield	Straw yield
T_1	916	2340	-	-
T_2	824	2130	-	-
T_3	990	2460	-	-
T_4	-	-	2774	5310
T_5	-	-	2709	4730
T_6	-	-	2641	5830
T_7	549	1350	1380	2570
T_8	-	-	-	-

T_1-Soybean + sunhemp (2:1) at 30 cm; T_2-Soybean + sunhemp (1:1) at 45 cm; T_3-Sole soybean at 45 cm; T_4-Maize + Sunhemp (2:1) at 45 cm; T_5-Maize + Sunhemp (1:1) at 30 cm; T_6-Sole Maize at 60 cm; T_7-Soybean + Maize (1:1) at 45 cm; T_8-Sole sunhemp at 30 cm.

Grain and straw yield of maize

The grain and straw yield of maize under different treatments has been shown in Table 4.5. The grain yield of maize ranged from 1380 kg ha^{-1} in treatment T_7 (Soybean + Maize (1:1) at 45 cm) to 2774 kg ha^{-1} in the treatment T_4 (Maize + Sunhemp (2:1) at 45 cm). The lowest seed yield of maize was recorded in treatment T_7. The treatment T_5 (Maize + Sunhemp (1:1) at 30 cm) and treatment T_6 (Sole Maize at 60 cm) recorded maize grain yield of 2709 and 2641 kg ha^{-1}, respectively. The straw yield of maize varied between 2570 and 5830 kg ha^{-1} among different treatments under study and followed the trend: $T_6>T_4>T_5>T_7$. The straw yield of maize was found higher under treatment T_6 (Sole Maize at 60 cm) followed by T_4 (Maize + Sunhemp (2:1) at 45 cm) (5310 kg ha^{-1}). The treatment in which the soybean and maize grown as intercropping at a spacing of 45 cm i.e. T_7 showed lowest straw yield (2570 kg ha^{-1}) whereas, the treatment T_5 recorded higher straw biomass of 4730 kg ha^{-1} than T_7 (Table 5).

Soybean equivalent yield

The soybean equivalent yield of soybean-maize sequence at the harvest of crops has been presented in Fig. 2. The Soybean equivalent yield (SEY) of crops ranged from 824 kg ha^{-1} to 1296 kg ha^{-1} under different treatments. The treatment T_4, T_5, T_6 and T_7 recorded significantly higher SEY as compared to the other treatments. The

treatments with soybean either alone or intercropped with green manure i.e. T_1, T_2 and T_3 showed significantly lower SEY.

Economics

The data on economic analysis is presented in Table 6. Economic analysis revealed that the highest net returns of Rs 21581 ha^{-1} and benefit: cost ratio of 2.25 was obtained due to the application of T_4 Maize + Sunhemp (2:1) at 45 cm followed by T_5 (T_5-Maize + Sunhemp (1:1) at 30 cm) with a net return of Rs. 20765 $Rs.ha^{-1}$ and benefit: cost ratio of 2.21.

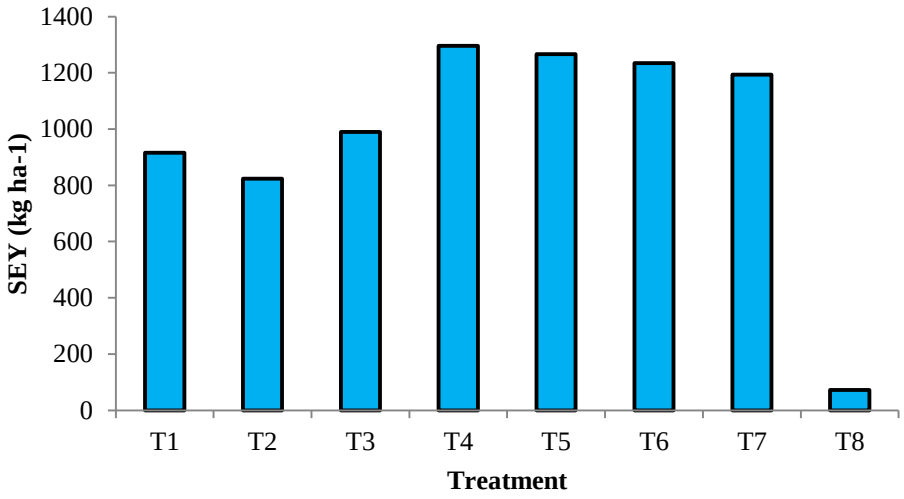

Figure 2. Effect of green manuring and intercropping on soybean equivalent yield (*T_1-Soybean + sunhemp (2:1) at 30 cm; T_2-Soybean + sunhemp (1:1) at 45 cm; T_3-Sole soybean at 45 cm; T_4-Maize + Sunhemp (2:1) at 45 cm; T_5-Maize + Sunhemp (1:1) at 30 cm; T_6-Sole Maize at 60 cm; T_7-Soybean + Maize (1:1) at 45 cm; T_8-Sole sunhemp at 30 cm).*

The data revealed that the treatments involving incorporation of sunhemp green manuring registered a reduction in 7-17% seed yield of soybean. Similarly, the straw yield of soybean also showed 5-13% and 45% reduction under green manuring and intercropping, respectively. The reduction in the seed and straw yield of soybean might be due to the no response effect of green manuring and intercropping on plant population. The maize grain yield showed 3-5% increment under green manuring while it was reduced by 48% in intercropping. The soybean equivalent yield (SEY) of soybean-maize sequence at the harvest of crops ranged from 824 kg ha^{-1} to 1296 kg ha^{-1} under different treatments. The treatment T_4, T_5, T_6 and T_7 recorded significantly higher SEY as compared to the other treatments. The treatments with soybean either alone or intercropped with green manure i.e. T_1, T_2 and T_3 showed significantly lower SEY. The SEY of the treatments involving maize showed higher than that of soybean (Fig. 2).

Table 6. Effect of green manuring and intercropping on Gross return, Net return and B: C ratio

Treatments	Cost of Cultivation	Gross return	Net return	B:C ratio
T_1	17700	27480	9780	1.55
T_2	18000	24720	6720	1.37
T_3	18700	29700	11000	1.59
T_4	17300	38882	21582	2.25
T_5	17200	37966	20766	2.21
T_6	17400	37017	19617	2.13
T_7	18500	35813	17313	1.94

Values in Rupeess ha^{-1} except B:C ratio; T_1-Soybean + sunhemp (2:1) at 30 cm; T_2-Soybean + sunhemp (1:1) at 45 cm; T_3-Sole soybean at 45 cm; T_4-Maize + Sunhemp (2:1) at 45 cm; T_5-Maize + Sunhemp (1:1) at 30 cm; T_6-Sole Maize at 60 cm; T_7-Soybean + Maize (1:1) at 45 cm; T_8-Sole sunhemp at 30 cm.

The increase in grain or seed yield under treatments of sole crop was due to lack of competition during entire crop season as compared to the other plots. Similar results were also noted by Thobatsi[13]; Sonam *et al.*[18] and Silwana and Lucas[19]. The sunhemp green manure crop produces 8.1–37.5 t ha^{-1} phytomass[20], 3.2-6.3 t/ha dry biomass[21] and accumulates 42-95 kg ha^{-1} N[22,23] which is utilized by crop for better performance. Also, higher N use efficiencies under green manure attributed to less N loss mechanisms than mineral N fertilizer and may therefore contribute to higher productivity[23]. A significantly higher yield of maize under green manure intercropping has already been reported widely by many researchers[24,33]. The positive effects of green manure intercropping on yield of rice[34-36], wheat[37,38], sorghum[39] and cotton[10,40] has already been reported earlier.

CONCLUSION

Green manure crop sunhemp intercropped with soybean and maize showed positive response in growth and yield attributes and yield of both the crops. Among the various treatments, intercropping of sunhemp with soybean (1:1) at 45 cm (T_2) and Maize + Sunhemp (1:1) at 30 cm (T_5) significantly increased crop growth and productivity and also reflected as economically viable technique.

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