Effect of long term integrated nutrient management on sustaining crop productivity and soil fertility under cotton and greengram intercropping in vertisols under semi arid agroecosystem of Maharashtra, India

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ABSTRACT

Cotton and greengram (1:1) is the most popular intercropping system in the dryland agriculture of Vidarbha region of Maharashtra, India. However, due to the erratic rainfall, rise in temperature, imbalanced fertilization and minimum use of organic manures, there is a continuous mining of nutrients resulting in deterioration of soil health. With the aim of maintenance of soil fertility for sustaining the desired crop productivity, a permanent plot experiment with the conjunctive use of organic and inorganic nutrient sources was conducted on Vertisols from 1987-88 to 2007-08 with cotton and greengram (1:1) intercropping system at the experimental field of All India Coordinated Research Project for Dryland Agriculture, Dr. PDKV, Akola, Maharashtra, India. The soil of the experimental site was low in available nitrogen and phosphorus and high in available potassium. The experiment was laid out with eight treatments consisting of recommended fertilizer dose (50:25:00 NPK kg ha^{-1}) to cotton through inorganics, 25kg N ha^{-1} (50% Recommended dose of nitrogen) through organic source i.e. Farm yard manure/ leucaena and combination of these organic sources with 50% inorganics. These treatments were replicated thrice in randomized block design. The results after twenty years of experimentation revealed that significantly highest yield of cotton and greengram with build up of soil fertility and maximum economic returns were obtained with the application of 25 kg N and 25 kg P_2O_5 ha^{-1} through Urea and single super phosphate and 25 kg N ha^{-1} through FYM over the years. Hence, it is concluded that, Integrated Plant Nutrient Supply (IPNS) system sustains fertility and productivity of soils in dryland agriculture.

Keywords: intercropping, dryland, IPNS, Productivity Rating Index, sustainable yield index, Vertisols

INTRODUCTION

Cotton is one of the important cash crop and plays vital role in the economy of the farmer as well as the country, thus it is popularly known as “White gold”. Several intercrops have been tried in cotton, among them greengram appears most suitable because it is a short duration leguminous crop which helps in preventing soil erosion and after harvesting the pods, biomass of greengram can be used as mulch in cotton crop. Now-a-days, the practice of intercropping of greengram in cotton is very popular with farmers and many dryland farmers are adopting it. The large scale production of food grains through application of chemical fertilizers is the base of green revolution but applications of large quantity of chemical fertilizers without considering the crop requirement adversely affect the microbial population. Use of chemical fertilizers to the crops is a common practice and hence the crop productivity is not satisfactory even after application of 100% Recommend dose of fertilizers. Due to increase in the inputs of cost, the profit margin of the farmer from crop produce is narrowing day by day. With the aim of maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefit from organic plant nutrient sources, it becomes necessary to minimize the expenses on fertilizers and at the same time sustain the crop yield and soil productivity by adopting integrated nutrient management approach. This practice not only increases the crop yield, but also improves physical, chemical and biological properties of soil [1].

MATERIALS AND METHODS

The present study was carried out on a long term integrated nutrient management experiment being conducted on the same site since 1987-88 with cotton and greengram intercropping system, without changing randomization. The experiment was laid out with eight treatments viz.,T_1-Control, T_2 - 50 kg N +25 kg P_2O_5 ha^{-1} fertilizers(RDF) , T_3 - 25 kg N + 12.5 kg P_2O_5 ha^{-1} fertilizers, T_4- 25 kg N ha^{-1} Leucaena , T_5- 25 kg N ha^{-1} FYM, T_6- 25 kg N + 25 kg P_2O_5 ha^{-1} fertilizers + 25 kg N ha^{-1} Leucaena , T_7- 25 kg N + 25 kg P_2O_5 ha^{-1} fertilizers + 25 kg N ha^{-1} FYM and T_8 - 50 kg N ha^{-1} Leucaena + 25 kg P_2O_5 ha^{-1} fertilizers. These treatments were replicated thrice in randomized block design and the recommended fertilizer dose of 50:25:00 NPK kg ha^{-1} was given to cotton through chemical fertilizers.

The soil of the experimental site was Vertisols which was initially (1987-88) low in available nitrogen (214.0 kg ha^{-1}) and phosphorus (29.70 kg ha^{-1}) and high in available potassium (264.0 kg ha^{-1}). Plot wise soil samples were collected after twenty years of experimentation and analyzed as per standard methods [2]. The data on various parameters such as yield of cotton and greengram, Productivity Rating Index (PRI), soil fertility, rainfall and its distribution in different years, Sustainable Yield Index(SYI) and economics of the cotton and greengram (1:1) intercropping system was worked out.

RESULTS AND DISCUSSION

The data in respect of pooled analysis of yield of cotton and greengram over the years (1987-88 to 2007-08) are presented in table 1. The long term impact of all treatments over control were statistically significant in respect of cotton as well as greengram under (1:1) intercropping system. The mean cotton yield ranged between 5.15 to 8.44 q ha^{-1} and greengram yield ranged between 3.85 to 5.79 q ha^{-1}. Application of 25kg N ha^{-1} (50% RDN) through organic source i.e. FYM/Leucaena lopping in combination with 25kg N and 25kg P_2O_5 ha^{-1} through urea and SSP (T_6 and T_7) recorded higher yields of both crops over the treatment 100% RDF (50:25:00 NPK kg ha^{-1}) through inorganic fertilizer (T_2). Significantly highest yield of cotton 8.44 q ha^{-1} and greengram 5.79 q ha^{-1} was obtained in treatment 25kg N and 25kg P_2O_5 ha^{-1} through urea and SSP with 25kg N ha^{-1} through FYM (T_7). Cotton and greengram yield performances of all the 100% RDF treatments were superior over the treatments of reduction of the 25kg nitrogen and its application through fertilizer (T_3) or Leucaena lopping (T_4).

Among the organics as a source of nitrogen, the treatment containing FYM recorded higher yields in the respective group of treatments over the Leucaena loppings in dryland conditions. Similar observations in respect of higher total productivity under cotton and mungbean (2:1) intercropping system were also reported by Shah *et al.* (2002) and Bismillah and Abdul(2004)[3,4]. Similar benefits of FYM and grain legumes in sustaining higher productivity were also reported by Sharma and Sharma(2006) and Ncube *et al.*(2007)[5,6]. The lowest mean yield of cotton (5.15q ha^{-1}) and greengram (3.85q ha^{-1}) was observed in the control (T_1).

Table 1. Long term effect of organic and inorganic nutrient sources on yield of crops and productivity rating index (Pooled).

Treatments	Pooled crop yields (q ha^{-1})		Productivity Rating Index (%)	
	Cotton	Greengram	Cotton	Greengram
T_1	5.15	3.85	43.0	64.2
T_2	7.37	5.05	64.1	87.9
T_3	6.72	4.76	56.0	79.4
T_4	6.58	4.72	54.8	78.7
T_5	7.08	5.02	59.0	83.6
T_6	7.69	5.20	62.7	86.6
T_7	8.44	5.79	70.4	96.5
T_8	7.52	5.27	61.4	84.3
SE (m) ±	0.197	0.106	-	-
CD at 5%	0.598	0.322		-
CV (%)	21.59	16.60	-	-

PRI indicates the productivity of the soil under specific treatment and management practices. The standard yield of the crops under experimentation was considered as a potential of the genotype to calculate the PRI. The standard yield of the cotton and greengram under the experimentation is 12 and 6 q ha^{-1}, respectively. The results (Table 1) indicated that under dryland conditions at Akola, maximum productivity of cotton was 70.4% and greengram was 96.5% obtained with 25kg N and 25kg P_2O_5 ha^{-1} through fertilizers with 25kg N ha^{-1} through FYM treatment (T_7) while the lowest productivity of cotton (43.0%) and greengram (64.2%) was observed in control (T_1). Thus, from the pooled yield data, it is revealed that, application of full recommended dose of nutrients (50:25:00 NPK kg ha^{-1}) is essential to obtain the maximum yield of cotton and greengram and substitution of 50% nitrogen in the RDF i.e. 25kg N ha^{-1} through FYM gave significantly highest productivity of both crops under the cotton and greengram intercropping system. On the basis of PRI, the maximum 70.4 and 96.5% yield can be achieved in dryland conditions of semi-arid tropics of Vidarbha region of Maharashtra, India. The green leaf manuring through leucaena lopping as nitrogen source and the reduction of 50% recommended nitrogen dose hampered the yield of both the crops in dryland conditions, may be due to the limited period of soil moisture availability which affect the *in-situ* decomposition and release of the plant nutrients during the growth period of the crops.

Soil analysis data obtained the significant effect of all treatments over control in respect to the available N, P_2O_5 and K_2O content of the soil over the years (Table 2). Before the start of the experiment in 1987-88, the organic carbon content of the experimental field was 0.46% and available N, P_2O_5 and K_2O content of soil were 214.0, 29.7 and 264.0 kg ha^{-1} respectively. After two decades of the experimentation the absolute control treatment under the cultivation of cotton and greengram as intercrop also recorded marginal improvement in the available N (218.57 kg ha^{-1}), available K (288.84 kg ha^{-1}) and organic carbon content (0.57 %) over the initial status of the soil, indicating that there is no deterioration of the fertility status of soil. This may be due to the fact that, black soils developed on basaltic parent material are rich in the plant nutrients except nitrogen and the intercropping of greengram, may satisfy the nitrogen requirement of crops through symbiotic fixation of atmospheric nitrogen. But, the available nutrient status of control was not able to meet the nutritional demand of the crop and hence yield performance (PRI) of the control treatment was only 43% for cotton and 64% for greengram.

The pooled experimental results presented in Table 2 showed that, there was a build up of organic carbon status of soil under cotton and greengram intercropping system in all treatments including control over the initial status (0.46%). The treatments receiving organic matter through

FYM and green leaf manuring of Leucaena lopping recorded improvement in the organic carbon content of the soil over control. However, significantly highest 0.71% soil organic carbon was recorded in 25kg N and 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through FYM treatment (T_7) and was at pat with 0.70% organic carbon content of 25kg N and 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through Leucaena lopping treatment (T_6). The organic carbon content in control (0.57%) was statistically equal to 100% RDF (0.58%) and 50% RDF (0.59) through inorganic fertilizer treatments.

Table 2. Long term effect of organic and inorganic nutrient sources on soil fertility.

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potash (kg ha^{-1})
T_1	0.57	218.57	24.98	288.84
T_2	0.58	245.27	30.24	321.15
T_3	0.59	233.26	28.72	315.70
T_4	0.66	235.68	30.40	326.98
T_5	0.67	243.87	31.18	360.62
T_6	0.70	252.09	32.62	353.05
T_7	0.71	252.22	33.79	377.38
T_8	0.67	245.17	32.23	345.38
SE (m) ±	0.010	4.613	0.543	6.249
CD at 5%	0.029	13.993	1.619	18.959
CV (%)	11.90	14.84	13.49	14.40

Soil, water and temperature are the limiting factors of the dryland agriculture and have direct influence on the soil organic carbon. Natural incorporation of the crop residues in the soil after harvest of the crop is common phenomenon, but year after year, continuous addition of the crop residues or green manuring or even FYM has a very little effect on soil organic carbon in dryland conditions. The soil moisture availability in dryland soils is only for a period of 150 days, which hamper the *in-situ* decomposition process of crop residues/green manures, on the other hand tremendous rise in summer temperature may result in oxidation of the organic carbon. Hence, under the dryland conditions only 1% organic carbon to the soil weight is considered as sufficient. The pooled data of this long term experimentation indicated the significant improvement and maintenance of the soil organic carbon content through judicious use of FYM/Leucaena loppings in combination with the inorganic fertilizers. Use of organic or inorganic plant nutrient sources alone was not helpful to build up organic carbon content of soils in dryland conditions. Similar build up of organic carbon with the conjunctive use of FYM alongwith inorganic fertilizers was also reported [7-9].

Atmospheric nitrogen is the primary source of the nitrogen to plant kingdom. Available nitrogen if not assimilated by the plant, either lost as water contaminant or vaporised to atmosphere. To evaluate the actual available nitrogen status of the experimental soil, the pooled over of available nitrogen data after every season was carried out and the results (Table 2) indicate that significantly superior 252.22 kg ha^{-1} available nitrogen was recorded with application of 25kg N and 25kg P_2O_5 ha^{-1} through Urea, SSP and 25kg N ha^{-1} through FYM (T_7) over T_1 (Control), T_3 (25kg N with 12.5kg P_2O_5 ha^{-1} through fertilizers) and T_4 (25kg N ha^{-1} through Leucaena lopping). However, increase in the available nitrogen content was at par with the available nitrogen content recorded in T_2, T_5, T_6 and T_8 treatments under experimentation. The specific trend was observed in respect of improvement in the available nitrogen content of soil, improvement to the tune of 252 kg ha^{-1} were recorded in treatments (T_6 and T_7) receiving 25kg N ha^{-1} through organic source out of 100% RDF

(50:25:00 NPK kg ha^{-1}) and to the tune of 245 kg ha^{-1} in the treatments of total 50kg nitrogen of 100% RDF either through fertilizers (T_2) or leuceana lopping (T_8), followed by 243 kg ha^{-1} in the treatment of only 25 kg ha^{-1} nitrogen through FYM (T_5) and the available nitrogen content of soil, 235 and 233 kg ha^{-1} were observed in the 25kg nitrogen alone through Leucaena lopping (T_4) and 50% RDF through fertilizers (T_3) treatments and lowest 218 kg ha^{-1} was observed in absolute control (T_1).

The results revealed that, the combined use of nitrogen sources such as fertilizer and organic matter is essential for improvement of available N content in soil. However, for the significant build up of soil available nitrogen, out of 100% RDF, supply of 50% N through FYM to cotton and greengram intercropping system in dryland conditions was highly beneficial. Similar observations were also recorded earlier [10-13]. The water soluble phosphoric acid is the plant readily available phosphorus present in the soil and the crops grown in neutral to alkaline condition, the mono-calcium phosphate (MCP) is supplied to crops through SSP. However, the unutilised MCP in soil react with calcium carbonate present in the soil and converted to di-calcium phosphate (DCP), later on tri-calcium phosphate (TCP) and become unavailable to growing plants. The Vertisols under experimentation are known for very high phosphate fixation capacity i.e. conversion of plant available phosphorus to unavailable form. The available P_2O_5 content of the soil over the period of experimentation (Table 2) indicate that, the treatments (T_6-T_8) receiving 25kg P_2O_5 ha^1 through SSP fertilizer in combination with organic material either FYM or Leucaena loppings recorded significantly higher content of available phosphorus over all other treatments (T_1-T_4). The maximum 33.79 kg ha^{-1} available phosphorus was observed in treatment 25kg N and 25kg P_2O_5 ha^{-1} through Urea and SSP in combination with 25 kg N ha^{-1} through FYM treatment (T_7) and it was at par with T_6 (32.62 kg ha^{-1}),T_8(32.23 kg ha^{-1}) treatments receiving organics with 25kg P_2O_5 ha^{-1} through SSP. However, increase in available phosphorus content in T_6 and T_8 was at par with T_5 (addition of 25 kg N through FYM alone). This might be due to the fact that for meeting out the 25 kg N ha^{-1}, the 5000 kg FYM ha^{-1} was added every year which may help to build up the available phosphorus status of the black soil over all other treatments those not containing organic matter.

Venugopalan and Pundarikakshudu(1999) [14] observed that substituting half the fertilizer N with FYM resulted in built up of available P. Significantly lowest 24.98 kg ha^{-1} available P was observed in control treatment. Thus, the results revealed that, due to the higher $CaCO_3$ content of the black soil as well as about 21% calcium content in the SSP fertilizer, the conversion of plant available phosphate to unavailable form may be increased, hence to overcome this and to make available maximum P_2O_5 to crop, the addition of FYM in combination with fertilizers is necessary. Similar observations were also recorded by [15, 16]. The black soils developed from Basalt rock have the major quantity of the mineral feldspars which are rich in K, Na and Ca and hence potash fertilizers are not recommended for the crops grown in black soils. The swelling and shrinkage property of black clayey soils trap the K ions in crystal lattice and become unavailable to plant. The data on integrated effect of the organics, inorganic fertilizers alone and their combinations on the available potash content of soil (Table. 2) revealed that even after non-application of potash fertilizer in any of the treatment under experimentation, there was improvement in the available potash status of the soil. Significantly highest 377.38 kg ha^1 available K_2O content in soil was observed in treatment T_7 i.e. 25kg N with 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through FYM and it was at par with 360.62 kg ha^{-1} available P_2O_5 in treatment of 5t FYM/ha (T_5). Treatment (T_5,-T_7) receiving FYM alone or in combination with fertilizers showed better performance over all other treatments, may be due to the fact that FYM contains 0.5% K_2O i.e. addition of 5t FYM ha^{-1} as a source of 25kg N ha^{-1} add about same quantity 25kg K_2O ha^{-1} to soil. Moreover, the humus part of the FYM after mixing with the soil may help to reduce the swelling and shrinkage capacity of soil via improvement in the soil structure. Thus, the results indicate that to exploit the inherent potential available potash supplying capacity of black soil, every year application of the FYM in combination with the inorganic fertilizers is necessary. Venkateswarlu *et al.* (2007) [17] also observed that annual incorporation of FYM/legume improved the soil properties and fertility status of the soil.

In general, significantly highest build up and content of soil organic carbon (0.71%), available N (252.22 kg ha^{-1}), available P_2O_5 (33.79 kg ha^{-1}) and available K_2O (377.38 kg ha^{-1}) were recorded in the treatment receiving 25kg N with 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through FYM through out experimentation period. The irregular monsoon rainfall and its erratic distribution is the main factor affecting to the agriculture in dryland regions. The rainfall and its monthly distribution data during the experimentation from 1987-88 to 2007-08 are graphically depicted in figure 1.

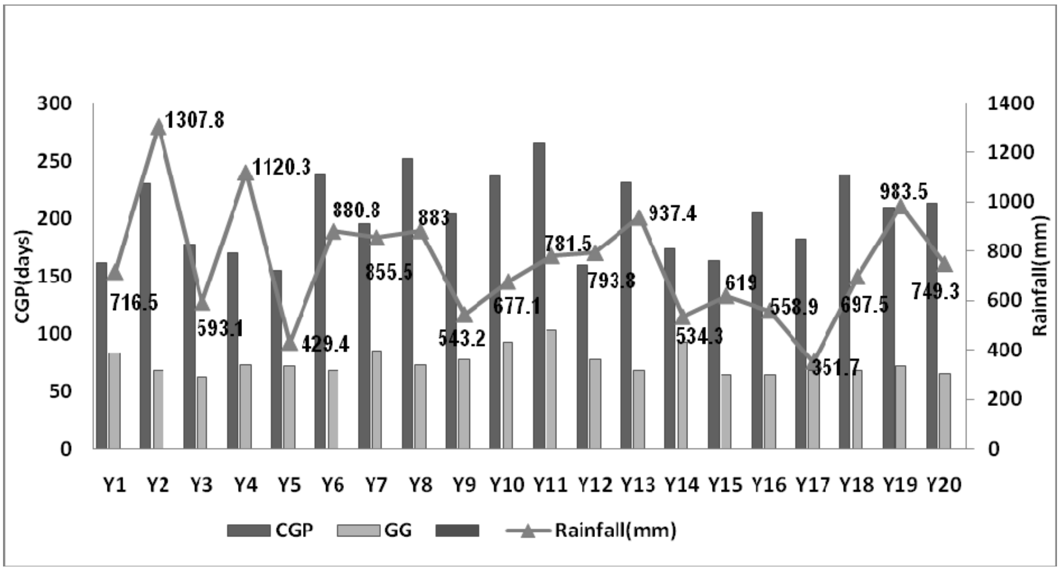

Fig. 1. Crop season rainfall and crop growth period during experimentation

From the data it is observed that, the crop season rainfall ranged between 351.7 mm in the year 2003 to 1307.8 mm in the year 1988, whereas, maximum nine years during the experimentation received rainfall between 500 to 750 mm followed by seven years in the range of 750 to 1000 mm. However, in four years period rainfall was below 500 mm and in only two years rainfall was above 1000 mm. The means of rainfall recorded in the above groups are 413.9, 632.1, 873.6 and 1214.5 mm, in <500, 500 to 750, 750 to 1000 and > 1000 mm, respectively. The rainfall and its distribution in the month of June determined the sowing dates of the crops in dryland regions. Overall, maximum rainfall was received in July and August. Depending upon the rainfall distribution there was a variation in the crop duration. The results of long term experimentation on cotton and greengram intercropping system in dryland condition revealed that, in maximum sixteen years the rainfall ranged between 500 to 1000 mm and the mean growing period of greengram was 76 days and for cotton was 209 days. Continuous less rainfall in couple of years (<500 mm) led to failure of the crops in second year (2003 & 2004). However, sufficient rainfall of previous year sustained the crop of next year in black soils of dryland regions. The 1120.3 mm rainfall received in 1990 sustained the crop of 1991 with 429.4 mm rainfall as well as only 558.9 mm rainfall received in 2002 provided sustenance to 2003 crop even with very less (351.7mm) rainfall.

In rainfed agriculture, sustainability of the yield becomes more important than simple mean as the magnitude of the yield is a rainfall dependent variable [18]. The Sustainable Yield Index (SYI) for each treatment was worked out using the respective mean yields of the treatment, standard error determined from the treatment wise regression quadratic model and maximum yield observed in any treatment during the study [19]. The SYI determined under crop season rainfall during the study period are presented in table 3. The data pertaining to the effect of INM on sustainable yield index of crops in cotton and greengram intercropping systems in rotation indicate that the highest SYI (0.70) was observed in treatment T_7 (25kg N with 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through FYM) followed by 0.60 in treatments T_6 (25kg N with 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through Leucaena lopping)and T_8 (50kg N ha^{-1} through Leucaena lopping with 25kg P_2O_5 ha^{-1} through fertilizers).

Table 3. Sustainable Yield Index (SYI) of cotton and greengram (1:1) intercropping system.

Treatment		SYI
T_1	Control	0.33
T_2	50kg N + 25kg P_2O_5 ha^{-1} through fertilizers	0.57
T_3	25kg N + 12.5kg P_2O_5 ha^{-1} through fertilizers	0.51
T_4	25kg N ha^{-1} through Leucaena lopping	0.49
T_5	25kg N ha^{-1} through FYM	0.54
T_6	25kg N + 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through Leucaena lopping	0.60
T_7	25kg N + 25kg P_2O_5 ha^{-1} through fertilizers and 25kg N ha^{-1} through FYM	0.70
T_8	50kg N ha^{-1} through Leucaena lopping + 25kg P_2O_5 ha^{-1} through fertilizers	0.60

In general, the average SYI values were found to be in the range of 0.33 to 0.70. Any practice yielding SI>0.66 is considered as recommendable, SI of 0.50 to 0.65 is considered as promising and SI<0.33 is undependable. From the pooled data (Table 4) of biological yields of cotton and greengram (1987-88 to 2007-08) it is revealed that, the highest gross monetary returns of Rs. 30272 ha^{-1} were obtained in treatment T_7 (25 kg N with 25 kg P_2O_5 ha^{-1} through fertilizers and 25 kg N ha^{-1} through FYM) followed by Rs.27463 ha^{-1} in T_6 (25 kg N and 25 kg P_2O_5 ha^{-1} through fertilizers and 25 kg N ha^{-1} through Leucaena lopping) and Rs.27169/ha in T_8 (50 kg N ha^{-1} through Leucaena lopping and 25 kg P_2O_5 ha^{-1} through fertilizers), while treatment of 100% RDF through inorganic fertilizers (T_2) recorded the gross monetary returns of Rs. 26409 ha^{-1} with 4th position. The highest gross monetary returns obtained in T_7 (25 kg N and 25 kg P_2O_5 ha^{-1} through fertilizers and 25 kg N ha^{-1} through FYM) reflected on the highest net monetary returns of Rs. 11598 ha^{-1} followed by 50 kg N with 25 kg P_2O_5 ha^{-1} through fertilizers (T_2) Rs. 11073 ha^{-1}. The lowest gross monetary returns and net monetary returns as Rs.19210 ha^{-1} and Rs. 5840 ha^{-1} respectively were obtained in control over the years.

Table 4. Economics of the cotton + greengram (1:1) intercropping system.

Treatments	Gross monetary returns (Rs ha^{-1})	Net monetary returns (Rs. ha^{-1})	B:C ratio
T_1	19210.00	5840.00	1.44
T_2	26409.00	11073.00	1.72
T_3	24417.00	9762.00	1.67
T_4	24022.00	6312.00	1.36
T_5	25711.00	8714.00	1.51
T_6	27463.00	8318.00	1.43
T_7	30272.00	11598.00	1.62
T_8	27169.00	4518.00	1.20

B:C - Benefit Cost Ratio.

The B:C ratio was calculated for testing the monetary income from the various treatments under study. The highest B:C ratio of 1.72 was recorded in treatment of 100% RDF through inorganic fertilizers (T_2) followed by 1.67 in the treatment receiving 25 kg N + 12.5 kg P_2O_5 ha^{-1} through fertilizers (T_3). Hence, on the basis of long term experimentation, it is concluded that, Integrated Plant Nutrient Supply system through application of 25kg N + 25kg P_2O_5 ha^{-1} through Urea (55kg) and SSP (156kg) and remaining 25kg N ha^{-1} through FYM (5000kg) to cotton and greengram (1:1) intercropping system sustains fertility and productivity of soil in dryland agriculture.

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REFERENCES

[1] Khiani KN and More DA. Journal of the Indian Society of Soil Science 1984,32: 372-393.
[2] Jackson ML. Soil chemical Analysis prentice Hall of India. Pvt. Ltd. New Delhi,1967, 498.
[3] Shah KH, Siddiqui SH, Memon MY, Imtias M, Aslam M. Asian Journal of Plant Sciences 2002, 1:358-360.
[4] Bismillah KM, Abdul K. Journal of Research (Science) 2004, 15: 23-31.
[5] Sharma SK, Sharma SN. Acta Agronomica Hungarica 2006, 54: 93–99.
[6] Ncube B, Steve JT, van Wijk, Mark T, John PD, Giller, EK. Plant Soil 2007, 299:1-15.
[7] Babhulkar PS, Wandile RM, Badole WP, Balpande SS. Journal of the Indian Society of Soil Science 2000, 48:89-92.
[8] Badole SB, More SD. Journal of Maharashtra Agriculture Universities 2000, 25:220-222.
[9] Bellakki MA, Badanur VP. Journal of the Indian Society of Soil Science 2000, 48:393-395.
[10] Chaudhary ML, Singh JP, Narwal RP. Journal of the Indian Society of Soil Science1981,29:81-85.
[11] Badanur VP, Poleshi CM, Naik BK. Journal of the Indian Society of Soil Science.1990, 38:426:429.
[12] Sharma RA. Crop Research 1999, 10:370-372.
[13] Katkar RN, Turkhede AB. Solanke VM, Wankhede ST. Journal of Cotton Research and Development 2002, 16:89-92.
[14] Venugopalan MV, Pundarikakshudu R. Nutrient Cycling in Agroecosystems 1999, 55:159-164.
[15] Prasad B, Singh AP. Journal of the Indian Society of Soil Science. 1980, 28:465-468.
[16] Bellakki MA, Badanur VP. Journal of the Indian Society of Soil Science. 1997, 45:438-442.
[17] Venkateswarlu B, Ramesh SG, Venkateswarlu S, Katyal JC. Soil Use and Management 2007, 23: 100-107.
[18] Maruthi Sankar GR, Mishra PK, Srinivasa Rao C, Padma Latha Y, Sahadev Reddy BM, Babu V S, Ravindrnath Reddy B, Veerabhadra Rao K, Bhargavi K, Ravindra Chary G , Osman M, Kumar S, Vasundhara S, Devasena GS and Girija A. Indian Journal of Dryland Agriculture Research and Development 2010, 25 (1): 36–38.
[19] Vittal KPR, Sankar GRM, Singh HP, Samra JS. Sustainability of Practices in Dryland Agriculture: Methodology and Assessment 2002, Central Research Institute for Dryland Agriculture, Hyderabad, Indian Council of Agricultural Research, India. 100pp.