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PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN SOYBEAN AS AFFECTED BY ORGANIC, CHEMICAL AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES

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SUMMARY

A field experiment was conducted for three consecutive years (2004-2006) to study the relative effect of organic, chemical and integrated nutrient management practices on physiological and biochemical changes in soybean. The study revealed that chemical nutrient management practice (CNMP) recorded higher chlorophyll and LAI. The photosynthetic rate was slightly higher in organic nutrient management practice (ONMP) than CNMP and integrated nutrient management practice (INMP) in the later years. On an average, the dry matter accumulation (DMA) was higher in CNMP and INMP than ONMP. The nitrate reductase activity (NRA) was higher in INMP in the first year whereas in the second and third years, it was higher in ONMP. Though the number of nodules was not affected by different nutrient management practices in the first two years, in the third year ONMP recorded significantly higher number of nodules. In the initial years, CNMP recorded higher seed yield than both ONMP and control. In the third year, ONMP recorded higher seed yield. The oil and mineral content of soybean was not affected significantly in all the three years of study. In conclusion, the growth and productivity of soybean was lower in ONMP in the initial years, but had recovered over a period of time.

Key words: **Chlorophyll, dry matter accumulation, LAI, NR activity, organic farming**

INTRODUCTION

Soybean is the most important grain legume crop in the world in terms of its use in human foods and livestock feeds. It is an important crop in central India and provides significant returns in many farm enterprises. Yields of the soybean crop will decrease when essential nutrients are deficient. Among the several constraints, improper nutrient management is important for low productivity. There is a need to work out nutrient management strategy to increase the production level. Chemical fertilizers play an important role to meet nutrient requirement of the crop but their continuous use on lands will have deleterious effects on physical, chemical and biological properties of soil, which in turn reflects on yield (Sarkar *et al*. 1997). Therefore, there is an urgent need to reduce the usage of chemical fertilizers and in turn increase the usage of organic manures which are known to improve physico-chemical properties of soil and supply the nutrients in available form to the plants. Further, because of the expected premium prices for the organically produced crops, there is a growing awareness among the farmers to cultivate crops under organic farming system (Ramesh *et al*. 2005). Therefore, present study was planned to find out the effect of organic, chemical and integrated management practices on some physiological aspects, yield and nutritional quality of soybean.

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MATERIALS AND METHODS

The field experiments were conducted during rainy season (June-October) for three consecutive years of 2004, 2005 and 2006 at the research farm of Indian Institute of Soil Science, Bhopal. The experiment consisted of four treatments, i.e. organic, chemical and integrated management practices and un-manured control. In organic nutrient management practice (ONMP), the nutrients were applied as cattle dung manure (3.75 t ha^{-1}) on the nitrogen equivalent basis. The phosphorus requirement of soybean crop was supplemented through rock phosphate (containing 13.9 % P) addition after adjusting the amount of P supplied through manures. The nutrient composition and quantity of organic manures applied is 0.8, 0.4 and 0.8 % N,P and K respectively. The organic manures were applied two weeks prior to sowing of crop. Weeds were controlled by hand weeding at 30 and 60 days after sowing of soybean and for the control of leaf eating caterpillar, neem oil (Azardiractin 0.03 %) was sprayed thrice at 30, 45 and 60 days after sowing of soybean. Dhaincha (*Sesbania aculeate*), a green manure crop was grown as a border crop around the soybean field. In chemical nutrient management practice (CNMP), nutrients were supplied through the chemical fertilizers, viz. urea, single super phosphate and muriate of potash and plant protection was through the recommended pesticides as and when required. In integrated nutrient management practice (INMP), 50 % of nutrients were supplied through organic manures and the rest 50 % through chemical fertilizers. Integrated pest management (IPM) practices were adopted for controlling the pests.

The observations on dry matter accumulation were recorded at 30, 60 days after sowing (DAS) and at harvest. The plant samples were then dried in an oven at 80^0C till constant weight is obtained. The leaf area was measured with a leaf area meter (Li-Cor Model LI-305A/4). The data on chlorophyll, photosynthetic rate, nitrate reductase activity (NRA) and number of nodules was recorded at 45 days after sowing. The chlorophyll pigment was extracted by a non-macerated method (Hiscox and Israelstam 1979) and the amount of chlorophyll was calculated using the formula given by Arnon (1949). The photosynthetic rate was measured with portable photosynthesis system (CID). The activity of nitrate reductase (NR) was determined using the method given by Hageman and Hucklesby (1971).

The experiment was conducted in a randomized block design and was replicated four times. Soybean (var. JS-335) was sown at a spacing of 45 X 5 cm in the first week of July and harvested in the second week of October. The total rainfall received during the rainy season (July-October) was 798, 888 and 1514 mm during 2004, 2005 and 2006 years, respectively. The data was analysed statistically and the treatment means were compared using LSD technique at 5% probability appropriate for RBD (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

The dry matter accumulation (DMA) of soybean as influenced by different nutrient management practices is given in Table 1. On an average, at 30 DAS, chemical nutrient management practice (CNMP) recorded higher DMA whereas at 60 DAS and at harvest, integrated nutrient management practice (INMP) recorded higher DMA. In general, CNMP recorded higher DMA in the initial years (2004 and 2005) particularly during the early stages of crop growth. During the third year (2006), the DMA in organic nutrient management practice (ONMP) was at par with that of INMP at 65 DAS and at harvest. All the nutrient management practices recorded significantly higher DMA compared to control. Increase in dry matter production of soybean with increasing rates of fertilizers was also reported by Nimje and Seth (1988).

Leaf area index (LAI) is defined as the area of the leaf per unit area of land surface. In soybean the maximum LAI values may range from 5 to 8 (Whigham, 1983).Leaf area is critical for crop light interception and therefore has a substantial influence on crop yield. Shibles and Weber (1965) reported that LAI of 3.2 was required for 95% light interception and 95% dry matter production. In the present study on an average CNMP recorded higher LAI at 30 DAS and INMP recorded higher LAI values at 60 DAS (Table 2). In the first year (2004), nutrient management practices did not affect the LAI of soybean at 30 DAS. In the second year (2005) higher LAI was recorded in INMP whereas, in the third year (2006), CNMP recorded higher LAI at 30 DAS.

Table 1. Dry matter accumulation (kg ha^{-1}) of soybean as affected by nutrient management practices

Nutrient management practice	30 DAS				60 DAS				Harvest			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
Organic	1051	1016	922	996	2754	3996	3691	3480	3134	4457	3199	3597
Chemical	1288	1323	1031	1214	3051	4262	3335	3549	3080	4476	3117	3558
Integrated	1149	1176	1048	1124	2893	4329	3573	3598	3069	4590	3240	3633
Control	786	932	641	786	2604	3456	2868	2976	2712	3983	2738	3144
LSD (0.05)	162	104	186		202	240	262		270	322	280	

Table 2. Leaf area index of soybean as affected by nutrient management practices

Nutrient management practice	30 DAS				60 DAS			
	2004	2005	2006	Mean	2004	2005	2006	Mean
Organic	1.14	1.43	1.29	1.29	2.89	3.59	5.16	3.88
Chemical	1.28	1.86	1.44	1.53	3.18	3.83	4.66	3.89
Integrated	1.14	1.66	1.46	1.42	3.06	3.89	5.00	3.98
Control	1.02	1.31	0.89	1.07	2.51	3.11	4.01	3.21
LSD (0.05)	NS	0.20	0.32		0.32	0.44	0.48	

At 60 DAS, CNMP recorded higher LAI during the first year (2004) whereas, in the second year (2005) INMP recorded higher LAI and in the third year (2006) ONMP recorded the higher LAI. Orellana *et al.* (1990) also reported that the application of fertilizers at the rate of 20 kg N with 35 kg P_2O_5 per hectare resulted in greater number of leaves and branches in Soybean.

The productivity of any crop depends on photosynthesis and partitioning of assimilates to economically important parts. The most important function of leaves is produce assimilates through photosynthesis and leaf chlorophyll contents are the key factors determining the rate of photosynthesis (Jain 1972) and dry matter production(Bellore and Mall 1975). Buttery and Buzzel (1977) reported that photosynthetic rate of soybean was highly correlated with chlorophyll content and suggested that initial screening of the progenies in a breeding programme for high photosynthetic rate could be done by measuring chlorophyll content. In the present experiment, the data on total chlorophyll content, NRA and number of nodules per plant was recorded at flowering stage (45 DAS) (Table 3). All the nutrient management practices recorded higher chlorophyll content than control. The mean of the three years data showed that CNMP recorded higher chlorophyll content. In the first year (2004), the chlorophyll content was not affected by nutrient management practices. However, in the second and third years (2005 and 2006) CNMP recorded higher chlorophyll content even though it was on par with ONMP. Nehra *et al.* (2001) also reported the increased chlorophyll content in wheat leaves due to the application of FYM and vermicompost.

The photosynthetic rate of soybean at flowering stage as affected by nutrient management practices is given in Fig.1. Application of manures either through organic, chemical or integrated nutrient management practice recorded higher photosynthetic rate compared to control. Among the nutrient management practices, CNMP and INMP recorded higher photosynthetic rate in 2004 and 2005 respectively and in the third year (2006), ONMP recorded higher photosynthetic rate.

Table 3. Total chlorophyll content, NRA and number of nodules in soybean 45 DAS as affected by nutrient management practices

Nutrient management practice	Total chlorophyll ($mg\ g^{-1}$ fw)				NRA ($\mu mol\ NO_2^-\ g^{-1}$ fw h^{-1})				No. of nodules $plant^{-1}$			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
Organic	2.98	2.62	3.51	3.04	37.7	39.6	38.9	38.7	21.6	64.8	70.2	52.2
Chemical	2.92	2.80	3.78	3.17	35.2	37.3	27.4	33.3	20.8	52.0	60.4	44.4
Integrated	2.95	2.71	3.26	2.97	38.5	32.3	33.4	34.7	19.4	53.5	65.1	46.0
Control	2.60	2.26	2.73	2.53	16.1	14.1	20.3	16.8	20.2	50.1	45.6	38.6
LSD(0.05)	NS	0.22	0.42		2.6	4.2	4.8		NS	NS	8.2	

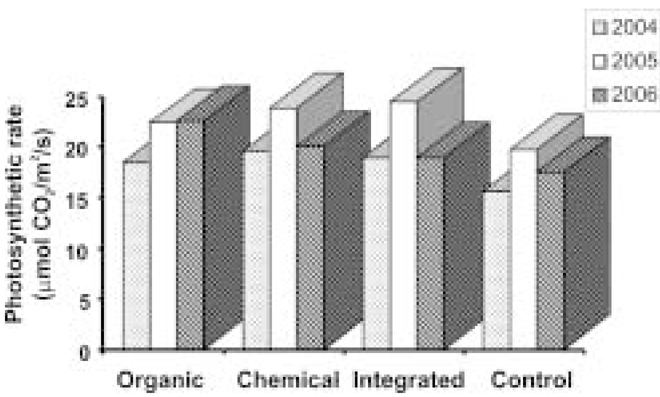

Fig.1. Photosynthesis rate of soybean as affected by nutrient management practices

Leaves are the most important contributor of biomass as they fix carbon dioxide through photosynthesis mechanism. The efficiency of leaves to produce assimilates and its persistence largely depends on photosynthetic pigments of which leaf chlorophyll content is of prime importance.

Nitrate reductase is the key enzyme for nitrogen assimilation as nitrate is the major N source for most of the higher plants (Campbell 1999). Higher NRA was recorded in INMP in the first year (2004) whereas in the second and third years (2005 & 2006) ONMP recorded higher NRA. Lowest NRA values were found in control treatment. In the first two years, the number of nodules was not affected by different nutrient management practices. However, in the third year ONMP recorded significantly higher number of nodules compared to CNMP but was on par with INMP. The results are in line with Kundu *et al.* (1993) and Datt *et al.* (2006) who reported that higher yield in Rajmash were related with higher N fixation and nodulation. Kundu *et al.* (1996) also noted an increase in N-fixation in soybean. Though the role of FYM in N fixation is not established, the increased seed yield and thus higher N fixation in FYM treated plots might due to availability of large amounts of photosynthates to both the nodules as well as seed because of better crop growth with additional nutrients supplied and better environment provided by FYM. Organic manure does not take part directly in N fixation, but its incorporation into the soil improves the soil physical conditions and provide conducive environment for proper establishment of Rhizobium and growth of nodules (Fried *et al.*1983). The increased NRA in ONMP treatment may be due to the release of appreciable quantities of nitrogen from the organic manures.

The yield components of soybean as affected by different nutrient management practices is given in Table 4. Chemical nutrient management practice recorded higher number of pods $plant^{-1}$ in 2004 and 2005 whereas in 2006,ONMP recorded higher number of pods $plant^{-1}$. The increase in grain yield of soybean due to nitrogen application may be because of the fact that nitrogen is important for the synthesis of Rubisco, chlorophylls and amino-acids which are the indispensable ingredients of the process of autotrophization. Nitrogen influenced the grain yield through higher production of photosynthates and their increased translocation to reproductive parts. Kumar and Rao (1991) found that seed yield of soybean

Table 4. Yield components and seed yield of soybean as affected by nutrient management practices

Nutrient management practice	Pods plant^{-1}				No. of seeds pod^{-1}				100 seed wt(g)				Seed yield (kg ha^{-1})			
	2004	**2005**	**2006**	**Mean**	**2004**	**2005**	**2006**	**Mean**	**2004**	**2005**	**2006**	**Mean**	**2004**	**2005**	**2006**	**Mean**
Organic	22.9	31.5	23.1	25.83	3.01	2.74	2.64	2.80	7.15	12.95	10.58	10.23	714	1399	918	1010
Chemical	29.9	35.6	20.3	28.60	2.96	2.82	2.54	2.77	7.59	12.38	10.43	10.13	775	1478	830	1028
Integrated	26.4	34.4	20.8	27.20	3.04	2.77	2.66	2.82	7.72	12.40	10.28	10.13	751	1437	876	1021
Control	20.2	30.1	16.3	22.20	2.70	2.71	2.34	2.58	7.10	11.92	9.45	9.49	634	1250	609	831
LSD(0.05)	2.1	2.2	1.8		0.20	NS	NS		NS	NS	0.62		NS	122	101	

increased with increase in nitrogen and phosphates rates from 0 to 40 and 0 to 100 kg per hectare, respectively. The number of seeds/pod was not affected by different treatments in 2005 and 2006. However, in 2004 INMP and ONMP recorded higher number of seeds/pod. Superior effect of combined use of urea and FYM on grain yield was reported by Tripathi *et al*. (1992). The 100-seed weight of soybean was not affected by different management practices in 2004 and 2005 but in 2006, ONMP recorded higher test weight. In the initial years (2004 and 2005), CNMP recorded higher seed yield than both ONMP and control. In the third year (2006), ONMP recorded higher seed yield compared to the other treatments. The reproductive growth depends on vegetative growth of plant. Higher vegetative growth increases LAI and supply of photosynthates for the formation of branches and other yield attributes. Jayapaul and Ganesaraja (1990) reported that increase in nitrogen and phosphate rates increased the number of pods per plant, seeds per pod and 100-seed weight in soybean.

The reduction of seed yields in ONMP during the initial years was due to lower photosynthesis rate, LAI, total chlorophyll and dry matter production. The higher seed yield in ONMP in the third year was due to the improvement of all these parameters. Since the nutrient release from organic sources is slow (Bharadwaj and Omanwar 1994), the crop responds better to chemical fertilizers than organic manures especially in the initial years. Organic nitrogen applied as manure is slowly available over a long period compared to chemical fertilizers. This often limits plant growth due to mismatch between crop nutrient demand and nutrient supply from organic sources, especially during initial phase of conversion from conventional to organic management systems (Pang and Letey 2000, Nasholm and Pearson 2001).

The quality parameters of soybean as affected by different nutrient management practices is given in Table 5. The differences in the protein content of soybean were prominent only in the first year of experimentation.

Table 5. Quality parameters of soybean as affected by nutrient management practices

Nutrient management practice	Protein (%)				Oil (%)				Mineral (%)			
	2004	**2005**	**2006**	**Mean**	**2004**	**2005**	**2006**	**Mean**	**2004**	**2005**	**2006**	**Mean**
Organic	36.28	37.10	36.37	36.58	18.95	19.05	18.93	18.98	**5.84**	5.05	5.27	5.39
Inorganic	35.81	37.60	36.25	36.55	19.02	19.12	19.32	19.15	5.87	5.12	5.30	5.43
Integrated	37.03	37.88	36.31	37.32	19.05	19.18	18.62	18.95	5.85	5.16	5.27	5.43
Control	33.60	36.81	35.87	35.42	18.50	18.95	18.45	18.63	5.60	5.01	5.13	5.24
CD(0.05)	1.02	NS	NS		NS	NS	NS		NS	NS	NS	

On an average, INMP recorded higher protein percentage compared to other nutrient management practices and control. The oil and mineral content of soybean was not affected significantly in all the three years of study. However, in general, application of nutrient through organic, chemical and integrated sources recorded slightly higher values of oil and mineral compared to control. The increase in oil and protein content under organic manure application could be assigned to the availability of all the essential nutrients in organic matter due to its continuous mineralization (Survase *et al.* 1986)

It can be concluded from the present study that soybean responded better to chemical and integrated nutrient management practices in the initial years of study. However, the organic nutrient management practice resulted in better growth and higher productivity in the later years.

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