Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 1962-1965
Received: 14-05-2018
Accepted: 18-06-2018

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Effect of long term application of fertilizers and manure on leaf area index, nodulation and yield of soybean in a Vertisol

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Abstract
The study was conducted on the Research Farm of Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur. The experiment was commenced in June 1972. The present study comprised of ten treatments i.e. 50% NPK, 100% NPK, 150% NPK, 100% NPK+HW, 100% NPK+Zn, 100%, 100%, 100% NPK+FYM, 100% NPK-S and control with four replications in simple randomized block design. Soybean Crop was raised with all the standard recommended agronomic practices other than those under treatments. The results on nodulation revealed that the maximum nodule number and dry weight of nodule was recorded when 100% NPK was supplemented with FYM whereas minimum was confined in control followed by N alone. The continuous application of fertilizer and manure resulted in significant response for grain and straw yield. The highest value of grain and straw was recorded in 100% NPK+FYM and lowest value in control.

Keywords: soybean, nodule, leaf area index and yield

Introduction
Long-term experiments are conducted with the aim for monitoring the impact of fertilizer management on soil fertility and sustainability of a production system (Dwivedi *et al* 2007) [2]. Real estimates of nutrient content during the crop growth will not only help in assessing the amount of fertilizer added to soil but will also help in assessing the soil fertility status to develop the strategies for crop production (Dwivedi *et al* 2015) [1]. Therefore, the objectives of this study confined to assess the yield response to applied fertilizers to determine the soil fertility status (FAI, 2014) yield and quality of crops in a 40-year-old soybean–wheat rotation on a Vertisol (Singh *et al*., 2012) [3].
In India is grown 11.67 million hectares with the production of 8.59 million tons (IASRI, 2017). Madhya Pradesh is a leading state in India for cultivation of soybean, where it is grown in 5.9 million hectares with the total production of 4.5 million ton (GGN International, 2016), M.P. in known as soybean state in the country (IIOES 2010). But the productivity is 737 kg/ha which is far below than its yield potential i.e. 2500 kg/ha (2016). Keeping the above point in view, the present study was carried out to observation the effect of integrated nutrient management on nodulation, LAI, uptake and yield of soybean in a Vertisol.

Materials and Methods
Ten plants were selected randomly from net plot area and tagged for recording observations. Almost all the morphological characters were recorded such as number of nodule, dry weight of and leaf area index nodules etc. at different growth stages (30, 45 and 60 DAS).

Number of nodules
Nodulation study was carried done at 25, 45 and 60 days after sowing by uprooting 10 plants per plot by placing notch and very carefully taking sample to avoid any losses or damage of nodules. The rhizosphere soil was washed in the running water. Nodules per plant were counted manually.

Dry weight of nodules
After counting, the nodules were detached from the roots and were kept in small paper bags and kept oven in hot air oven at 60^0C for 3-4 days (till constant weight) to record their dry weight.

Leaf Area Index (LAI)
LAI expresses the ratio of leaf surface (one side only) to the ground area occupied by the plant or a crop stand worked out as per specification of Gardner *et al*. (1985).

Grain and straw yield

Crop was harvested and bundles were made plot wise, and allowed to dry in the plot for 2-3 days and then weighed. After threshing was done plot wise, straw and grain yield was recorded. Samples were drawn for chemical analysis

Results and Discussion

Leaf area index

Leaf area index (LAI) expresses the ratio of leaf surface (one side only) to the ground area occupied by the crop. It also described the functional size of assimilatory apparatus of other growth parameters (Watson 1947, 1952). The assimilatory surface area of a crop stand and its increase has a direct bearing on the amount of solar energy intercepted by canopy and represented the productive capacity of a crop. A progressive pattern of LAI accumulation was noted with treatment 100%. NPK + FYM at various stages of the crop age up to 75 DAS treatment its starts to decline (Table 1).

It is also observed that the leaf area was increased as growth of the plant progressed from early to maturity in the regard the lower LAI was found 30 DAS and increase at 45 DAS to 60 DAS. The data on LAI recorded at 30, 45 and 60 DAS revealed that highest LAI of 2.64, 3.14 and 4.12 respectively were obtained in100%NPK+ FYM treatment, while lowest values were in control treatment (1.44, 1.62 and 1.94).

LAI increased significantly with 100% NPK + FYM (30, 45, 60 DAS of the followed by 100% NPK & 150% NPK. Integrated use of NPK+FYM% resulted in significantly higher LAI than control. Greater LAI in NPK + FYM treatment was attributed to production of new leaves & also increase in size of the existing leaves. However among the NPK + FYM treatment the difference in the LAI was not statistically significant. While other showed the leaf area LAI, is increases as compared to control due to balance use of NPKS @ 20:40:20:kg/ha, FYM (Singh and Singh, 2014) [5]. A linear treatment of increase in LAI was noted 45 and 60 DAS (Table 1) these after decline sharply. The maximum leaf area was expressed by treatment 100% NPK+FYM (30, 45 and 60 DAS) followed by 100% NPK and 150% NPK (Bandopadhyay *et al* 2010, Singh *et al*. 2014) [5] and Verma (2017)

Table 1: Effect of long term application of fertilizers and manure on LAI at 30, 45 and 60 DAS

Treatment	30 DAS			45 DAS			60 DAS		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
50 % NPK	2.00	2.05	2.02	2.11	2.31	2.21	2.89	2.50	2.69
100% NPK	2.48	2.42	2.45	2.59	2.81	2.70	3.34	3.11	3.22
150% NPK	2.45	2.69	2.57	2.71	3.05	2.88	3.55	3.67	3.61
100%NPK+ HW	2.41	2.59	2.50	2.58	2.91	2.74	3.24	3.33	3.29
100%NPK + Zn	2.37	2.57	2.47	2.57	2.72	2.64	3.40	2.89	3.14
100%NP	2.07	2.23	2.15	2.26	2.58	2.42	2.47	2.48	2.47
100 % N	1.67	1.70	1.68	1.79	1.80	1.79	2.34	2.37	2.35
100%NPK + FYM	2.51	2.77	2.64	2.79	3.49	3.14	4.07	4.17	4.12
100%NPK – S	2.34	2.39	2.37	2.51	2.44	2.48	3.22	3.25	3.23
Control	1.46	1.42	1.44	1.65	1.59	1.62	1.96	1.92	1.94
SEm±	0.08	0.16	0.13	0.05	0.21	0.15	0.16	0.17	0.16
CD (*p=0.05*)	0.223	0.47	0.36	0.15	0.60	0.43	0.46	0.50	0.47

Number of nodule and their dry weight

The data shows (Table 2) that different dose of fertilizer affect the number of nodules significantly at 30, 45 and 60 DAS. Nodules number at 30 DAS 22.5 and 14.1were recorded in 100%NPK+FYM and control treatments, respectively. However, at 45 DAS number of root nodules per plant was significantly higher compared to control (46.6 and 30.6) but at 60 DAS (45.4 and 30.1) 1were recorded in 100%NPK+FYM and control treatments. Weight of nodules per plant (Table 3) was recorded significantly maximum in 100% NPK+FYM at 45 and 60 after sowing having 0.71 and 0.68 g respectively. However, minimum weight of nodules per plant was obtained in control 0.43 and 0.42 g at 45 and 60 respectively. The nodulation was significantly increased in sub optimal, optimal and super optimal doses of fertilizer over control because this nodulation process was very sensitive resulted in to the available levels of nutrient combinations, thereby extreme imbalances of nutrition reduced the counts to even zero. Addition of FYM with 100 per cent NPK showed a maximum and significantly higher nodulation over sub optimal dose. Similar results were reported by Nimje and Seth (1987), Nickolas *et al* 2006, Cheng *et al*. (1999) and Chandrol (2017).

Table 2: Effect of long term application of fertilizers and manure on nodulation at 30, 45 and 60 DAS

Treatment	30 DAS			45 DAS			60 DAS		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
50 % NPK	15.50	17.00	16.25	35.14	37.25	36.19	37.93	38.25	38.09
100% NPK	17.55	18.68	18.11	38.55	39.38	38.96	39.42	40.22	39.82
150% NPK	19.47	20.25	19.86	42.91	44.08	43.49	44.00	46.00	45.00
100%NPK+ HW	17.49	18.61	18.05	38.50	39.00	38.75	42.00	43.16	42.58
100%NPK + Zn	16.67	18.50	17.59	38.38	38.73	38.55	41.54	42.13	41.83
100%NP	15.50	16.75	16.13	36.41	36.15	36.28	36.83	37.50	37.17
100 % N	14.83	15.23	15.03	31.38	32.25	31.81	32.54	33.80	33.17
100%NPK + FYM	22.44	22.75	22.59	44.25	46.58	45.42	45.25	48.00	46.63
100%NPK – S	17.19	18.57	17.88	35.03	37.48	36.25	38.17	39.00	38.59
Control	13.38	14.88	14.13	28.73	31.50	30.11	30.75	30.63	30.69
SEm±	0.71	0.64	0.67	1.23	1.40	1.35	2.06	1.83	1.91
CD (*p=0.05*)	2.06	1.85	1.89	3.57	4.07	3.83	5.97	5.31	5.42

Table 3: Effect of long term application of fertilizers and manure on dry weight of nodule 30, 45 and 60 DAS

Treatment	30 DAS			45 DAS			60 DAS		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
50 % NPK	0.18	0.19	0.18	0.58	0.60	0.59	0.54	0.55	0.54
100% NPK	0.22	0.23	0.22	0.61	0.61	0.61	0.60	0.62	0.61
150% NPK	0.24	0.24	0.24	0.63	0.65	0.64	0.62	0.65	0.63
100%NPK+ HW	0.21	0.22	0.21	0.62	0.63	0.62	0.61	0.62	0.61
100%NPK + Zn	0.21	0.22	0.22	0.62	0.63	0.62	0.60	0.62	0.61
100%NP	0.18	0.19	0.18	0.52	0.54	0.53	0.54	0.54	0.54
100 % N	0.16	0.17	0.16	0.48	0.47	0.47	0.46	0.48	0.47
100%NPK + FYM	0.27	0.29	0.28	0.70	0.73	0.71	0.68	0.69	0.68
100%NPK – S	0.19	0.21	0.20	0.58	0.60	0.59	0.57	0.58	0.57
Control	0.15	0.14	0.15	0.42	0.44	0.43	0.41	0.43	0.42
SEm±	0.010	0.011	0.010	0.03	0.03	0.03	0.04	0.03	0.04
CD (*p=0.05*)	0.030	0.033	0.032	0.096	0.10	0.10	0.12	0.10	0.11

Grain and Straw Yield of Soybean

The perusal of the data (Table 4) indicated that the lowest grain yield (450 kg ha^{-1}) was recorded in control. While, it was found to be increased (600 kg ha^{-1}) in treatment receiving sub optimal fertilizer dose (50% NPK), which was significantly higher than that obtained with application of 100% N alone (538 kg ha^{-1}). These results indicated that even if 50% of recommended optimal dose applied it was found to be much beneficial in comparison to the application of imbalanced nutrient application. Application of recommended optimal dose (100% NPK) resulted in productivity of grain yield for 725 kg ha^{-1} but exclusion of sulphur (i.e. 100% NPK-S) dose had resulted in comparatively lower grain yield (963 kg ha^{-1}) amounted to decline yield of soybean for about 23.68%. Similar results have also been observed by Hati *et al*. (2006) and Kundu *et al*. (2007). On the other hand, the grain yield obtained in 100% NPK + FYM treatment (1488 kg ha^{-1}) was significantly higher than 150% NPK treatment (1113 kg ha^{-1}). The data clearly indicated that addition of integrated application of fertilizer with FYM was found to be beneficial for maintaining the fertility of the soil as well as subsequently improving the productivity potential of soybean-wheat cropping system (Sonune *et al*. 2003) and Dwivedi and Dwivedi (2015) [1]. Similarly, it was also found that 100% N treatment resulted in yield (538 kg ha^{-1}) and progressively increased to 665 kg ha^{-1} when P fertilizer (100% NP) was included in fertilizer schedule. While, there was a further improvement noted when K nutrient included (100% NPK) for around 725 kg ha^{-1} over imbalanced NP application and accounted for 6.0% increased. These results established the importance of phosphorous application and found to be a major fertility constraint in controlling productivity of soybean grown especially in black soil (Kushwaha *et al*. (2017) and Dwivedi *et al*. 2007) [2] Similar, trend of was also noticed in case of straw yield.

Table 4: Effect of long term application of fertilizers and manure on of Soybean (kg ha $^{-1}$) during two years

Treatments	Grain		Pooled	Straw		Pooled
	2015	2016		2016	2017	
50% NPK	625	681	653	1646	1556	1601
100%NPK	900	906	903	1864	2019	1942
150%NPK	1150	1038	1094	1891	2113	2002
100%NPK+ HW	875	894	884	1725	2006	1866
100%NPK+ Zn	855	888	871	1850	2100	1975
100%NP	605	800	703	1842	1825	1833
100%N	325	438	381	1109	1488	1298
100%NPK+ FYM	1200	1075	1138	1900	2179	2039
100%NPK-S	750	844	797	1793	1919	1856
Control	313	394	353	1084	1444	1264
SEm±	39	116	41	101	121	112
CD (*p=0.05*)	114	40	115	294	353	323

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