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Impact of Long-term application of fertilizers and manure on productivity and quality determinants of soybean grown on Vertisols

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Abstract
A long term field experiment on different doses of fertilizers along with integration of organic manure in soybean- wheat cropping sequence is in progress at the Jawaharlal Nehru Agricultural University, India since 1972. The effect of continuous fertilizer application on soil nutrient status was evaluated after 43 years of cropping cycle on a Vertitisol with ten treatments replicated four times. The results revealed in the maximum chlorophyll synthesis was noticed when 100% NPK with FYM was practiced. Application of fertilizer in balance amount was also found to have a prominent effect on chlorophyll a, chlorophyll b, total chlorophyll content and Carotenoid content in soybean leaves at 30, 45 and 60 days, stage of growth which was found to increase with successive addition of higher dose of fertilizer over 100% N alone and control. The data also indicated that highest grain yield of soybean was obtained in treatment receiving optimal dose of NPK along with organic manure (100% NPK + FYM) on the contrary and the lowest yields of soybean was recorded with imbalance fertilizer addition and control. However, integrated application of fertilizer with organic manure noticed remarkable higher content of protein and oil content in soybean crop grown on a Vertisol.

Keywords: Long term fertilization, soil fertility, leaf, protein, oil and chlorophyll

Introduction
It has been established that important physiological attributes such as leaf area index (LAI), crop growth rate, relative growth rate net assimilation rate (NAR) and specific leaf weight can address various constraints for improving the productivity potential of crop [1]. The highest dry matter accumulation occure when the LAI attains its maximum value within the shortest possible time [2]. It has also been observed that physiological mechanisms of soybean flower and pod abscission are hormonally mediated, might involve in changing flowering pattern and abscission. A mixture of Gibberellic acid and S-abscisic acid, a plant growth regulator influenced growth and yield in various crops [3-4]. Long-term fertilizer experiments are conducted with the aim of monitoring the impact of different nutrient management practices on soil fertility status and sustainability. Nutrient status is one of the key parameters to assess the fertility status of soil. It has been noticed that Correct estimates of nutrient content during growth of soybean will not only help in assessing the amount of fertilizer added to soil but also helps in assessing the fertility status of soil in developing the strategies for sustainable production [5]. Therefore, the objectives of this study confined to assess the response to applied fertilizers on soil fertility status yield and quality of crops in a four-year decades old soybean–wheat sequence a Vertisol.

Materials and Methods
The present investigation is a part of the All India Coordinated Research Project (AICRP) ongoing long-term fertilizer experiment initiated during 1972. The experiment consisted of 10 treatments replicated four times in a randomized block design consist of gross plot size 17x10.8 m with 1 m spacing between plots and 2 m spacing between the replications. The recommended fertilizer dose (100% NPK) for the crop was estimated on the basis of soil test values. The research study involved diverse works as study changes in soil quality, crop productivity and sustainability in Soybean–Wheat cropping system. The soil under experiment represent a medium deep black soil classified as very fine, belonging to Kheri series of fine *montmorillonitic hyperthermic* family of Typic *Haplustert.* At the initiation of this experiment in 1972. The initial status of available nutrients is presented in table (1).

Physiological Growth Determinants

Leaf Area Index (LAI)

LAI was worked out as per specification of Gardner *et al.* (1985) [12].

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}} \quad LAI = \frac{LA_2 + LA_1}{2} / P$$

Where, the LA_1 and LA_2 represents the leaf area during two consecutive intervals and "P" unit ground area.

Leaf Area Duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. It reflects the extent of seasonal integral of light interaction and correlates with yield. LAD was computed as follows: (Watson, 1952).

$$LAD = \frac{(LA_2 + LA_1)}{2} \times (T_2\text{-}T_1)\ (cm^2/day)$$

Where, the LA_1 and LA_2 represent the leaf area at two successive time intervals (T_1 and T_2).

Determination of chlorophyll and carotenoid content

Leaf chlorophyll (a, b and total) and carotinoids content was estimated by acetone extraction method (Yoshida, 1972).

Results and Discussions

Physiological growth parameters

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 [6]. 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 and sulphur at various stages of the crop age up to 75 DAS treatment however the LAI was found to be decline progressively on growth of plant observed till maturity [7-8].

LAI increased significantly with 100% NPK + FYM (30, 45, 60 DAS followed by 100% NPK & 150% NPK. Integrated use of NPK+FYM resulted in significantly higher LAI over control. This higher LAI in NPK + FYM treatment was attributed to efficient photo synthetically production increase in size of the existing leaves. However among the NPK + FYM treatment the difference in the LAI was not statistically significant [9] while other showed the leaf area LAI, CGR and seed yield of lentil is increases as compared to control due to balance use of NPKS @ 20:40:20:20kg/ha, FYM) [10] Integrated application of organic manure along with chemical fertilizer increased leaf area index (LAI), total dry matter (TDM) chlorophyll content in leaf tissues as compared with inorganic fertilizer alone [11]

Leaf area duration (LAD) express the magnitude and persistence of leaf area and leafiness during the period of crop growth [12] similarly LAD may express the ability of plant to produce and maintain leaf area and efficiency to assimilation during growing season which is described as the leaf area duration [6] and it is also called as the photosynthesis potential [13]. The LAD is significantly dependent on the maintenance of photo synthetically active assimilatory surface area which is the product of rate of initiation and size of assimilatory surface area. These processes are influenced by both genetic as well as environment factor such as nutrient management.

A linear increase was observed in LAD while it was found to be decline after 45 to 60 DAS. The maximum leaf area duration was expressed 100% NPK+FYM (30, 45 and 60 DAS) followed by 100% NPK and 150% NPK [9, 14].

Content of Chlorophyll and Carotenoids

The leaf chlorophyll and carotenoid content in soybean leaves at various physiological growth stages was significantly influenced by fertilizer as well as integrated nutrient application. In this regard, higher application of the fertilizer alone or in combination increased the chlorophyll a, chlorophyll b and total chlorophyll content at 30, 45 and 90 days of crop growth over imbalanced fertilizer addition. This could be due to the role and contribution of balance fertilizer involved with synthesis of chlorophyll and carotinoids in assimilatory portion of the plant leaves [15]. The synthesis of chlorophyll and carotinoids was influenced with advancement of growth stages hence, higher content of leaf chlorophyll and carotenoids was estimated at pre flowering (30 DAS), general flowering (45 DAS) and declined sharply during pod fill (60 DAS) in soybean [16]. The increased content of leaf chlorophyll and carotenoids in reproductive phase seems to be due to increased supply of balance nutrition specially Sulphur nutrition which apparently increased the availability of iron by creating favorable cellular environment due to adequate availability of feed at the sites of porpyrin biosynthesis. This may lead to greater synthesis of photosynthetic pigments in the active assimilatory zones. The concentration of these pigments was found to be greatly influenced by the application of NPK and S nutrient [7] thus the practical consequence of this effect is self-explanatory that other factors being favorable the greater amount of the solar energy utilized and convert to higher dry matter production [8]. In this connection the balance fertilizer application resulted in greater amount of chlorophyll a, b and total chlorophyll content. While lowest content was noted with 100% N alone and control. Similar finding has also been reported by +.

The increased pigments may be due to more availability of NPK, and micronutrients through organic manures. Carotenoids are the important accessory photosynthetic pigments and a non-enzymatic antioxidant in plants.the variation carotenoids content significantly affected with organic and inorganic nutrients uptake by plants. [7, 17] reported increased isoflavanoids (carotenoids related compounds) in FYM applied soybean. The increased carotenoids content could be due to efficient functioning of metabolic system involved in carotenoids biosynthesis under the influence of liberal supply of essential plant nutrient namely NPK, S and micronutrients through integrated application of organic manures.

Grain and Straw Yield

The perusal of the data 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}). Application of recommended optimal dose (100% NPK) resulted in higher productivity of grain for 725 kg ha^{-1} but

exclusion of sulphur (i.e. 100% NPK-S) 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 [18, 19]. 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 [20]. 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) and resulted in 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 [21-22] Similar, trend was also noticed in yield of straw at harvest of crop.

Table 1: Effect of continuous application of fertilizers and manure on LAI and different growth stage of soybean

Treatments		LAI		
		40 DAS	60 DAS	90 DAS
T_1	50%NPK	2.23	3.12	2.28
T_2	100%NPK	3.13	3.91	2.85
T_3	150%NPK	3.56	4.54	3.22
T_4	100%NPK+HW	3.11	3.60	2.43
T_5	100%NPK+Zn	2.98	3.60	2.60
T_6	100%NP	2.68	3.25	2.32
T_7	100%N	1.82	2.79	1.72
T_8	100%NPK+FYM	3.74	4.76	3.83
T_9	100%NPK – S	2.13	3.19	2.38
T_{10}	Control	1.68	2.10	1.43
SEm±		0.10	0.17	0.10
CD (P=0.05)		0.29	0.48	0.29

Table 2: Effect of continuous application of fertilizers and manure on LAD and different growth stage of soybean

Treatments		LAD (cm^2. day)		
		40 DAS	60 DAS	90 DAS
T_1	50%NPK	48.01	54.71	45.70
T_2	100%NPK	60.17	61.83	54.81
T_3	150%NPK	77.68	69.65	62.72
T_4	100%NPK+HW	52.92	59.41	50.08
T_5	100%NPK+Zn	55.58	58.08	51.57
T_6	100%NP	53.97	54.67	45.14
T_7	100%N	39.82	45.19	38.40
T_8	100%NPK+FYM	77.13	60.31	55.40
T_9	100%NPK – S	47.72	48.41	45.70
T_{10}	Control	34.56	40.80	36.05
SEm±		2.82	1.95	2.15
CD (p=0.05)		8.20	5.66	6.245

Table 3: Effect of continuous application of fertilizers and manure on content of Chlorophyll a, b, total and Carotenoids in soybean leaves

Treatments		Chlorophyll-a (mg g^{-1})			Chlorophyll-b (mg g^{-1})			Total chlorophyll (mg g^{-1})			Carotenoids (mg g^{-1})		
		I	II	III	I	II	III	I	II	III	I	II	III
T_1	50%NPK	1.59	1.76	1.24	0.91	1.16	0.83	2.51	2.93	2.07	0.77	0.85	0.68
T_2	100%NPK	1.96	2.08	1.76	1.29	1.36	1.00	3.25	3.44	2.76	0.84	0.85	0.77
T_3	150%NPK	2.10	2.31	1.96	1.48	1.58	1.16	3.58	3.89	3.12	0.92	0.92	0.86
T_4	100%NPK+HW	1.80	2.07	1.85	1.17	1.33	0.93	2.97	3.40	2.81	0.73	0.81	0.71
T_5	100%NPK+Zn	1.72	1.95	1.65	1.05	1.31	0.86	2.77	3.26	2.51	0.69	0.76	0.73
T_6	100%NP	1.71	1.98	1.67	0.91	1.22	0.84	2.62	3.20	2.51	0.68	0.74	0.65
T_7	100%N	1.41	1.63	0.91	0.78	0.85	0.68	2.19	2.48	1.59	0.60	0.65	0.53
T_8	100%NPK+FYM	2.15	2.44	2.17	1.65	1.67	1.35	3.80	4.11	3.53	0.93	0.96	0.88
T_9	100%NPK – S	1.46	1.53	1.18	0.78	0.92	0.65	2.25	2.45	1.83	0.63	0.70	0.55
T_1	Control	1.19	1.49	0.80	0.62	0.75	0.61	1.81	2.24	1.41	0.56	0.62	0.54
SEm±		0.04	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.39	0.09	0.03	0.04
CD (p=0.05)		0.12	0.16	0.16	0.14	0.16	0.14	0.16	0.14	0.52	0.13	0.10	0.08

Note: I = 45 DAYS, II = 60 DAYS, III = 75 DAYS

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