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Impact of Integrated Nutrient Management on Mean Single Leaf Area, SPAD Chlorophyll Readings, Dry Matter Partitioning and Yield of Maize (*Zea mays* L.)

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Abstract An experiment was conducted in two consecutive years 2010 and 2011 during *kharif* season to evaluate impact of nutrient management on mean single leaf area, SPAD chlorophyll meter reading, phenological studies, dry matter partitioning and yields of maize (*Zea mays* L.). Experimental findings revealed that mean single leaf area by different plant parts of maize at 30, 45, 60 DAS and at harvest, was recorded under 100% NPK+ FYM 10 t ha^{-1}. The dry matter accumulation at 30 and 45 DAS revealed that application of 100% NPK with FYM 10 t ha^{-1} showed maximum dry weight of leaves and stem. The highest SPAD chlorophyll meter reading were noted under the influence of 150% NPK. The soil fortified with 100% NPK+FYM 10 t ha^{-1} recorded maximum grain, stover and biological yield of maize.

Keywords Maize, Dry matter partitioning, FYM, Yield, Mean single leaf area.

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Introduction

Improving and maintaining soil quality for enhancing and sustaining agricultural production is of utmost importance for India's food and nutritional security. Increased food production, a boon of green revolution had led the country to a state of self sufficiency and pulled the country out of the ship to mouth existence. Among the various food crops, cereals namely rice and wheat has been under the main focus of this revolutionary progress. However, maize, the queen of cereals occupies a pride place among cereal crops in India. It has emerged as third most important food crop after rice and wheat as it represents 24% of total cereal production. It is a staple food for the vast rural population of our country. Maize is cultivated in diverse production environments ranging from temperate hill zone of Himachal Pradesh to the semi arid region of Rajasthan. Amongst the growth inputs, mineral nutrients play a vital role not only in exploitiong the realizable potential of the crop, but also to maintain sustainability of soil for agricultural production.

Table 1. Impact of nutrient management on mean single leaf area and SPAD chloroohyll meter reading in maize.

	Mean single leaf area (cm^{-2})								
	30 DAS			45 DAS			60 DAS		
Treatments	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
100% NPK	116.39	115.80	116.09	325.71	323.80	324.75	359.58	357.47	358.52
100% NPK + Zn	116.97	116.23	116.60	324.01	322.11	323.06	366.50	364.35	365.43
100% NPK + S + Zn	115.69	114.59	115.14	325.96	324.05	325.00	360.29	358.18	359.23
100% NPK + S	118.06	115.76	116.91	323.42	321.53	322.48	360.58	358.47	359.53
100% NPK+*Azotobacter*	116.77	114.66	115.71	307.23	305.42	306.32	363.41	361.28	362.34
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	121.36	119.61	120.48	320.77	318.89	319.83	364.35	362.21	363.28
100% NPK+FYM 10 t ha^{-1}	127.34	125.35	126.34	335.54	333.58	334.56	376.60	374.39	375.49
FYM 20 t ha^{-1}	104.21	101.78	102.99	266.89	265.33	266.11	322.99	321.10	322.04
150% NPK	122.08	120.24	121.16	329.49	327.56	328.52	344.31	341.30	342.81
100% NP	109.56	108.06	108.81	319.02	317.15	318.09	330.67	328.73	329.70
100% N	104.14	102.56	103.35	279.37	277.73	278.55	307.75	305.95	306.85
Control	93.05	92.11	92.58	207.98	206.76	207.37	274.15	272.54	273.34
SEm±	4.31	4.54	3.13	9.82	9.80	6.93	11.55	11.00	7.97
CD (p=0.05)	12.40	13.07	8.84	28.25	28.19	19.58	33.24	31.64	22.52

Table 1. Continued.

				SPAD chlorophyll meter reading					
	At harvest			30 DAS			45 DAS		
Treatments	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
100% NPK	282.01	280.36	281.19	41.31	42.89	42.10	47.14	44.90	46.02
100% NPK + Zn	286.86	285.18	286.02	42.39	42.07	42.23	46.70	45.18	45.94
100% NPK + S + Zn	293.31	291.59	292.45	44.78	43.00	43.89	49.95	46.38	48.16
100% NPK + S	281.40	279.75	280.57	43.37	42.22	42.80	47.90	46.10	47.00
100% NPK+*Azotobacter*	283.24	281.58	282.41	43.90	43.48	43.69	46.26	46.30	46.28
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	295.88	294.15	295.02	41.10	43.29	42.19	45.63	46.68	46.15
100% NPK+FYM 10 t ha^{-1}	325.01	315.65	320.33	47.69	46.02	46.85	51.31	48.25	49.78
FYM 20 t ha^{-1}	262.33	260.80	261.56	39.15	38.19	38.67	44.24	41.00	42.62
150% NPK	301.27	299.51	300.39	47.26	43.28	45.27	52.40	48.08	50.24
100% NP	272.37	270.77	271.57	41.97	41.80	41.88	44.42	41.53	42.97
100% N	256.70	255.20	255.95	41.37	39.60	40.49	45.25	39.78	42.51
Control	231.34	229.99	230.67	38.50	27.85	33.17	40.91	28.38	34.64
SEm±	9.59	8.85	6.53	1.00	1.18	0.78	1.05	1.06	0.75
CD (p=0.05)	27.60	25.46	18.43	2.89	3.40	2.19	3.02	3.06	2.11

An exhaustive review of the nutrient balance sheet of Rajasthan agriculture reveals that constant mining of nutrient elements through crops and subsequent insufficient addition of these nutrients to the soil in the form of manures and fertilizers has tilted it in a negative balance [1]. In recent years the deterioration in soil health associated with global predicament of energy along with escalation in the prices of chemical fertilizers lead to emphasize on supplementation of chemical fertilizers with low priced nutrient sources such as organics and biosources [2]. The aim is to integrate natural and manmade resources of plant nutrients supply so as to increase crop productivity in an efficient and environmentally favorable manner without diminishing soils inherent capacity of plant nutrient supply.

Table 2. Impact of nutrient managment on dry matter partitioning and phenological observation of maize.

	Dry matter partitioning (g)								
	30 DAS						45 DAS		
	Leaf			Stem			Leaf		
Treatments	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
100% NPK	8.30	8.24	8.27	13.77	13.60	13.69	12.99	12.59	12.79
100% NPK + Zn	8.33	8.25	8.29	12.91	12.72	12.82	13.20	12.80	13.00
100% NPK + S + Zn	9.30	9.27	9.28	14.60	14.43	14.52	13.52	13.12	13.32
100% NPK + S	8.82	8.76	8.79	13.05	12.87	12.96	13.78	13.38	13.58
100% NPK+*Azotobacter*	7.84	7.81	7.82	13.97	13.80	13.88	14.05	13.66	13.86
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	8.64	8.62	8.63	15.08	14.91	15.00	16.00	15.63	15.81
100% NPK+FYM 10 t ha^{-1}	9.45	9.20	9.33	15.42	15.26	15.54	16.94	16.58	16.76
FYM 20 t ha^{-1}	7.67	7.65	7.66	12.27	12.07	12.17	12.69	12.29	12.49
150% NPK	9.19	9.15	9.17	14.74	14.57	14.65	14.42	14.03	14.23
100% NP	8.88	8.84	8.86	11.89	11.69	11.79	14.31	13.92	14.11
100% N	8.18	8.15	8.17	12.02	11.83	11.92	12.80	12.40	12.60
Control	4.35	4.31	4.33	10.79	10.58	10.69	9.10	8.66	8.88
SEm±	0.29	0.28	0.20	0.46	0.47	0.33	0.49	0.49	0.35
CD (p=0.05)	0.83	0.81	0.57	1.33	1.35	0.93	1.41	1.42	0.98

Table 2. Continued.

	Phenological observations								
	45 DAS								
	Stem			Days to tasseling			Days to silking		
Treatments	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
100% NPK	36.29	36.00	36.14	45.75	45.00	45.38	52.50	52.00	52.25
100% NPK + Zn	36.14	35.85	35.99	46.00	45.50	45.75	52.50	52.30	52.40
100% NPK + S + Zn	40.44	40.19	40.31	45.50	45.50	45.50	52.75	52.50	52.63
100% NPK + S	36.69	36.40	36.55	46.00	45.75	45.88	52.25	52.00	52.13
100% NPK+*Azotobacter*	35.91	35.62	35.76	45.00	44.75	44.88	54.00	53.50	53.75
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	36.19	35.90	36.04	46.00	45.75	45.88	52.54	52.30	52.42
100% NPK+FYM 10 t ha^{-1}	41.16	40.92	41.04	45.75	45.25	45.50	54.50	54.30	54.40
FYM 20 t ha^{-1}	33.39	33.06	33.22	45.00	44.50	44.75	52.50	52.00	52.25
150% NPK	40.85	40.60	40.73	46.50	46.00	46.25	55.00	56.00	55.50
100% NP	34.04	33.72	33.88	45.00	44.75	44.88	52.75	52.50	52.63
100% N	32.36	32.02	32.20	45.00	44.75	44.88	51.50	51.30	51.40
Control	25.08	24.68	24.88	43.00	42.50	42.75	51.00	50.00	50.50
SEm±	1.25	1.26	0.89	1.44	1.43	1.02	1.64	1.66	1.17
CD (p=0.05)	3.58	3.62	2.50	NS	NS	NS	NS	NS	NS

Materials and Methods

A field experiment was carried out under long term fertilizer experiment initiated in *kharif* of 1997 in two successive years during *kharif* of 2010 and 2011 at Instructional Farm, Rajasthan College of Agriculture, Udaipur to assess the effect of continuous application of plant nutrients through organic and inorganic sources and its combination on mean single leaf area, SPAD chlorophyll reading, phenological observation and yield of maize. The experiments consisted of twelve treatments viz. 100% NPK (T_1), 100% NPK + Zn (T_2), 100% NPK + Zn+S (T_3), 100% NPK + S (T_4), 100% NPK+seed treatment with *Azotobacter* (T_5), FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM) (T_6), 100% NPK + FYM 10 t ha^{-1} (T_7), FYM 20 t ha^{-1} (T_8), 150% NPK (T_9), 100% NP (T_{10}), 100% N (T_{11}) and absolute control (T_{12}) were replicated four times in randomized block.

The sources used for applying N, P and K were area, di-ammonium phosphate (adjusted for its N control) and muriate of potash respectively. Gypsum and zinc sulfate ($ZnSo_4.7H_2O$) were used to supply S and Zn. The other sources of nutrients were FYM (farm yard manure) and biofertilizer (*Azotobacter* sp.). The dose of the NPK for maize was worked out according to the soil test fertilizer recommendeation. The 100% NPK dose in kg ha^{-1} worked out was 120:60:30 for maize crop. The doses for sulfur and zinc were framed as 40 kg S ha^{-1} and 5 kg Zn ha^{-1} respectively while FYM was applied as per the treatments. Maize variety PEHM-2 was sown at the seed rate of 25 kg ha^{-1} at inter row of 60 cm and plant to plant spacing of 20 cm.

Results and Discussion

Mean single leaf area

Maximum MSLA at 30 DAS was recorded by integrated use of 100% NPK + FYM 10 t ha^{-1} in both the years and on pooled basis. It was at par with 150% NPK and FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM) where as 45 DAS maximum MSLA was observed with treatment having 100% NPK+FYM 10 t ha^{-1} but the effect of this treatment was at par to 100% NPK, 150% NPK, 100% NPK+Zn, 100% NPK+S+Zn, 100% NPK+S, 100% NPK (-NPK of FYM) and 100% NP. At harvesting stage 100% NPK+FYM 10 found superior to all treatments except 150% NPK. The magmitude of increase in MSLA at harvesting stage due to these two treatments were to the tune of 38.86 and 36.08% over control (230.67 cm^{-2}).

SPAD-502 chlorophyll mater reading

The SPAD values of the treatment 100% NPK + FYM 10 t ha^{-1} was highest however, it was closely followed by those obtained by fortifying the soil with 150% NPK at 30 DAS both the years and as well as on pooled basis (Table 1). At 45 DAS maximum value of SPAD chlorophyll meter reading was noted under 150% NPK, its effect was at par to 100% NPK + FYM 10 t ha^{-1} and 100% NPK + S + Zn. The intensity of green color of maize depends on chlorophyll content that is affected by a number of factors. The degree of nitrogen supply and color of plant are interrelated and the same finding was also observed by Scharf and Lory [3].

Dry matter partitioning

A reference to data (Table 2) indicates that soil en-

Table 3. Impact of nutrient management on grain, stover and biological yield of maize.

	Yield (kg ha^{-1})								
	Grain			Stover			Biological		
Treatments	2010	2011	Pooled	2010	2011	Pooled	2010	2011	Pooled
100% NPK	3408	3194	3301	5218	4749	4984	8626	7944	8285
100% NPK+Zn	3595	3290	3442	5507	4871	5189	9102	8161	8631
100% NPK+S+Zn	3690	3487	3589	5556	5187	5371	9246	8674	8960
100% NPK+S	3460	3274	3367	5324	4845	5085	8784	8119	8452
100% NPK + *Azotobacter*	3508	3377	3442	5342	4991	5167	8850	8368	8609
FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM)	3469	3440	3454	5322	5201	5261	8791	8640	8716
100% NPK + FYM 10 t ha^{-1}	4075	3912	3994	6055	5618	5836	10130	9530	9830
FYM 20 t ha^{-1}	2360	2364	2362	3540	3487	3514	5900	5851	5876
150% NPK	3777	3698	3737	5567	5585	5576	9344	9282	9313
100% NP	2950	2779	2865	4556	4197	4376	7506	6976	7241
100% N	2337	2137	2237	3687	3274	3480	6024	5411	5718
Control	1438	1285	1362	2241	1940	2091	3679	3226	3452
SEm±	103	106	74	165	184	124	199	287	174
CD (p=0.05)	297	304	208	475	529	349	573	824	493

richment with 100% NPK + FYM 10 t ha^{-1} resulted in greatest dry weight of leaves and stem (9.33 and 15.34 g $plant^{-1}$) at 30 DAS on pooled basis. The maximum accumulation of dry matter by maize leaves and stem at 45 DAS were recorded by soil fortification with 100% NPK with FYM 10 t ha^{-1}, which result in 88.73 and 64.95% increment in leaves and stem respectively over control.

Phenological observations

The reference to data (Table 2) indicates that the crop under balanced and integrated fertilization did not significantly differ in regard to days to tasseling and silking over unfertilized control in both the years as well as pooled basis. The data also reveal that application of 150% NPK observed maximum number of days in respect to tasseling and silking.

Yields

The highest grain yield was recorded by application of 100% NPK + FYM 10 t ha^{-1} and its performance was at par with 150% NPK in both the years (Table 3). Next in order of superiority was 150% NPK. The treatment receiving 100% NPK and its combination with Zn, Zn+S, *Azotobabcter* seed treatment and FYM 10 t ha^{-1} + 100% NPK (-NPK of FYM) showed statistically equivalent results in raising grain yield on pooled basis. The application of 100% NPK with FYM 10 ha^{-1} produced highest stover yield (5836 kg ha^{-1}) on pooled basis and the result of which was statistically at par to 150% NPK. The maximum biological yield (9830 kg ha^{-1}) was also recorded with 100% NPK and its combination with FYM 10 t ha^{-1}. The overall improvement in crop growth under the influence of optimum nutrition involving combination of all nutrients and increasing role of fertility levels could be ascribed to their potential role in modifying soil and plant environment conducive for better development of both morphological and biochemical components of the plant growth that increase efficiency of physiological processes of plant system [4, 5].

The significant effects of these parameters as a consequence of FYM in conjugation with chemical fertilization are attributed to the favorable nutritional status of soil resulting into increased biomass production of the crop. This may also be attributed to favorable effect of FYM on microbial activity and root proliferation in soil which caused solubilizing effect on native phosphorus and other nutrients. However, as fertilizer dose increased, the beneficial effects decreases because due to excessive use of fertilizers resulting in over exploitation of nutrients, particularly micronutrients [6—9].

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