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Response of Organic and Inorganic Nutrient Sources on Growth, Productivity and Nutrient Content of Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted at college farm of Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India to evaluate the influence of integrated application of different nutrient sources on growth, yield and nutrient content of wheat (*Triticum aestivum* L). Experiment was conducted in a randomized block design with three replications. Under different nutrient sources, *i.e.* control, 50 to 100% RDF, FYM 5 t ha^{-1}, biofertilizers and their combined application were done. Findings exhibits that the application of 75 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB in wheat, significantly enhanced all growth (dry matter, chlorophyll content, total tillers, CGR, RGR and others) & yield attributes (Effective tillers, test weight and others), grain yield (4.12 t ha^{-1}) and as

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quality, nutrient (N, P, K) content and protein content of wheat over rest of treatments, but it remained statistically at par with 100 % RDF+5 t FYM ha^{-1}+ *Azotobacter*+PSB (grain yield 4.18 t ha^{-1}). Thus, it is concluded that for better nutrient management, an integration of organic, inorganic and biofertilizers sould be done. With application of 75 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB, there is 25% saving of nutrients as compared to 100 % RDF+5 t FYM ha^{-1}+ *Azotobacter*+PSB.

Keywords: Azotobacter; CGR; RGR; nutrient content; yield.

1. INTRODUCTION

Wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] is the most important staple food crop of the world and emerged as the backbone of India's food security [1,2]. Wheat is most important and remunerative *rabi* cereal crop of India not only in terms of acreage, but also in terms of its versatility for adoption under wide range of agro climatic conditions and crop growing situations. Wheat is second most important crop next to rice and it contributes nearly one third of total food grain production. It is good supplement for nutritional requirement of human body. It contains 10-12 % protein and 65-70 % carbohydrates [3]. Wheat straw is also used as dry fodder for livestock. India holds second position after china in the world with regard to area and production of wheat. In India, wheat is grown on 31.61 m ha area and produces 109.52 mt with average productivity of 3464 kg ha^{-1} [4]. In Rajasthan, the area for wheat is 3.93 mha, production 12.21 mt with productivity of 3885 kg ha^{-1} [5].

Wheat yield is highly variable within different agro-ecologies of India, due to variable climatic conditions, genotypes, seeding time and practices; and other management practices [6]. Factors responsible for low productivity of wheat in arid region of Rajasthan are low fertility status and poor physical condition of soil, inadequate and imbalance fertilizer use and emergence of multiple nutrient deficiency. Therefore, augmenting nutrient supply assume prime significance to improve its productivity.

Being the exhaustive crop, wheat requires huge amount of nutrients for producing higher yields. Long term studies being carried out at several locations in India indicated that application of all the required nutrients through chemical fertilizers have deteriorating effect on soil health, many environmental problems including soil, air and water pollution and leading to unsustainable yields [7,8]. Thus, demand for chemical fertilizers can be lowered by supplementing the nutrients through organic manures [9,10]. Although, organic manure alone cannot produce the sufficient food for present population [11]. Thus, integration of chemical, organic and biofertilizer sources and their management have shown promising results not only in sustaining the productivity but have also proved effective in maintaining soil health and enhanced nutrient use efficiency [12,13]. It has also evidence that biofertilizers like *Azotobacter* and Phosphate solubilizing bacteria (PSB) alone or in combination have great prospect for increasing productivity of wheat. Systematic use of diverse sources for nutrients viz., biofertilizers, organic manures and inorganic fertilizers has been also known to improve B:C ratio of fertilization, agronomic efficiency in wheat based cropping system [14]. Keeping all these points in view the present investigation was aimed to evaluate the response of different nutrient sources and their combination on wheat production.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted at College of Agriculture, Swami Keshwanand Rajasthan Agricultural university, Bikaner (28.01°N, 73.22^{0}E, 234.7 m above mean sea level) during *rabi* season of 2014-15 to 2015-16 (November to April). Bikaner falls under Hot Arid Eco-region. The average annual rainfall of the tract is about 260 mm which is mostly received during the rainy season. Soils are loamy sand with 0.109% organic carbon (Walkley-Black C), alkaline $KMNO_4$- oxidizable-N 120.4 kg ha^{-1}, 0.5 M $NaHCO_3$-extractable P 18.68 kg ha^{-1} and 1 N NH_4OAc-extractable K 214.6 kg ha^{-1}.

2.2 Experimental Design and Treatments

Experiment was laid out in a randomized block design with three replications comprising different treatment combinations *i.e.* control, 50 %, 75 % and 100 % RDF, 50 % RDF+FYM (5 t ha^{-1}), 75 % RDF+FYM (5 t ha^{-1}), 100 % RDF+FYM (5 t ha^{-1}), 50 % RDF+FYM (5 t ha^{-1})+*Azotobacter*+PSB, 75 % RDF+FYM (5 t ha^{-1}

^{1})+*Azotobacter*+PSB and 100 % RDF+FYM (5 t ha^{-1})+*Azotobacter*+PSB, applied in wheat (with gross plot size of 39 m^2/plot) comprising total 10 treatment combinations. The recommended dose of fertilizer for wheat was 120 kg ha^{-1} N, 40 kg ha^{-1} P_2O_5 and 20 kg ha^{-1} K_2O. Half dose of nitrogen and full dose of phosphorous and potassium was applied basal at the time of sowing. Remaining nitrogenous fertilizer was applied in 2 equal splits – at first irrigation and second irrigation. FYM was applied before sowing of wheat on the nitrogen-equivalent basis and requirement of crop in respective treatments. Seeds of wheat were treated with *Azotobacter* and PSB in respective treatments at the time of sowing. The wheat 'Raj-3077' was sown at 20 cm row spacing on 20th and 26th November during 2014 and 2015, respectively and harvested on date 1th and 8th April 2015 and 2016, respectively.

2.3 Methods and Formulas

Different growth and yield attributes of wheat were studied *viz.,* The plants from 0.25 m row length were cut from the ground level (excluding the root portion) for the periodical observations of dry matter production. The harvested plant material was air dried first and then in an oven at 60^{0}C to constant weight. Total dry weight of plants were averaged to record dry matter m^{-1} row length (g). The sample taken for dry matter estimation were also used for calculating CGR (Crop Growth Rate) per plant at periodical intervals from 0 to 30, 30 to 60, 60 to 90 and 90 to 120 DAS with the following formula given by Hunt [15]:

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{W_2 - W_1}{(T_2 - T_1)A}$$

Where W_2 and W_1 were the total dry weight at T_2 and T_1 time of observation and A is area.

The relative growth rate of a plant at an instant time (t) was calculated with the help of following formula and expressed in mg g^{-1} day^{-1} (Radford) [16].

$$\text{RGR (mg g}^{-1}\text{ day}^{-1}) = \frac{(\ln W_2 - \ln W_1)}{t_2 - t_1}$$

Where, L_n is the natural log, w_1 and w_2 are crop dry weight at time t_1 and t_2 respectively.

For chlorophyll content, treatment wise fresh leaf sample of 0.1 g was taken and ground in 80 per cent acetone, filtered from filter paper No. 42 and volume was made up to 25 ml. The resultant intensity of colour was measured in UV-VIS spectrophotometer 118 (systronics) at specific wave length (645 mμ and 663 mμ) to estimate chlorophyll 'a' and chlorophyll 'b' content (Arnon) [17].

$$\text{Chlorophyll 'a' content (mg g}^{-1}) = \frac{12.7\, A_{663} - 2.69\, A_{645}}{a \times 1000 \times w} \times V$$

$$\text{Chlorophyll 'b' content (mg g}^{-1}) = \frac{22.9\, A_{645} - 4.68\, A_{663}}{a \times 1000 \times w} \times V$$

Where,

a = Length of light path in cell (usually 1 cm), w = Fresh weight of leaf samples (g), v = Volume of extract (ml)

Total chlorophyll content (mg g^{-1}) = Chlorophyll 'a' + Chlorophyll 'b'

The representative samples of seed and straw drawn were used to analyze N, P, K content and protein content. Yield attributes *viz.,* effective tillers m^{-1} row length (no.), number of grains $spike^{-1}$. A seed sample was taken from the produce of each of the net plot harvested and 1000 seeds were counted and weighed to record as test weight in grams. The representative samples grains as well as straw of wheat crop collected at harvesting were dried in hot air oven at 60 ^oC for 48 hours. The oven-dried samples were ground to pass through 40 mesh-sieve and analysed for nitrogen, phosphorus and potassium concentration. Nitrogen was estimated by Kjeldahl's method [18], P concentration by Vanado-molybdo-phosphoric yellow colour method [19] and K concentration by Flame Photometer method [19]. The uptake of nutrients was computed by multiplying the concentrations with dry weight of respective plant parts. The grain, straw and biological yields of each net plot (inclusive of tagged plants) were recorded in kg $plot^{-1}$ after cleaning the threshed produce were converted into t ha^{-1}. Benefit: Cost ratio was calculated by dividing the gross returns from total cost of cultivation. In order to test the significance of variance in experiments, the data obtained for various treatment effects were statistically analysed as per procedure described by Panse and Sukhatme [20].

3. RESULTS AND DISCUSSION

3.1 Growth Attributes of Wheat

Different nutrient treatments in wheat involving 75 and 100 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB significantly enhanced various growth parameters over control and other treatments. Among the different tested nutrient sources, application of 75% RDF + 5t FYM + *Azotobacter* + PSB recorded the maximum dry matter accumulation, CGR and RGR which being at par with 100% RDF + 5t FYM + *Azotobacter* + PSB, 100% RDF + 5t FYM and 75% RDF + 5t FYM. But in case of total tillers it was at par with 100% RDF + 5t FYM + *Azotobacter* + PSB, 100% RDF + 5t FYM and 100% RDF. 75 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB resulted in significantly higher growth attributes *i.e.,* chlorophyll content and other attributes of wheat and found at par with 100 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB (Table 1 & Table 2) on pooled mean basis [21]. Under this study, the greater availability of nutrients in soil due to increase in fertilizer application that might have enhanced meristematic activity (multiplication and elongation of cells), which leads to increased plant height and dry matter accumulation as supported by [22,23,24].

Under integrated application of fertilizers and FYM with biofertilizers seems to be on account of increase in chlorophyll content, which is considered main determinants of dry matter production [25]. With integrated use of FYM and NPK might led to improve photosynthetic area of plants, meristematic activity, nutrient uptake and its further reflectance into the increased growth parameters [24]. Due to application of FYM, soil pH is reduced. This reduced soil pH has considerable influence on availability of most of the essential plant nutrients [26]. This increased availability of macro and micro nutrients, which in turn quick absorption of nitrogen, phosphorus, potash and helped in expansion of leaf area, provided greater photosynthetic surface to intercept more radiant energy and net photosynthesis supported by Nitharwal et al. [27], which finally improved the growth of the crop. Application of biofertilizers causes considerable increase in plant height and tillering, ultimately enhanced the dry matter production [28,29].

3.2 Yield Attributes and Yield of Wheat

With integrated use of nutrients, significant positive influence on yield attributes (effective tillers, grains $spike^{-1}$ and others) which finally led to higher yield of crop, but test weight was not significantly influenced. Effective tillers, grains $spike^{-1}$ improved significantly with 75% RDF + 5t FYM + *Azotobacter* + PSB but remained at par with 100% RDF + 5t FYM + *Azotobacter* + PSB and 100% RDF + 5t FYM. Wheat grain, straw and biological yields were significantly higher with the application of different nutrient sources than the control (Table 2 and Figure 1). Incorporation of 75 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB resulted in significantly higher grain yield (4.12 t ha^{-1}) of wheat as compared to other treatments, but it was at par with 100 % RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB (4.18 t ha^{-1}), similar findings were reported by other authors [30,31]. The positive impact of availability of individual plant nutrients and humic substances from organic fertilizers and balanced supplement of nitrogen through inorganic fertilizers might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of yield parameters [21,32].

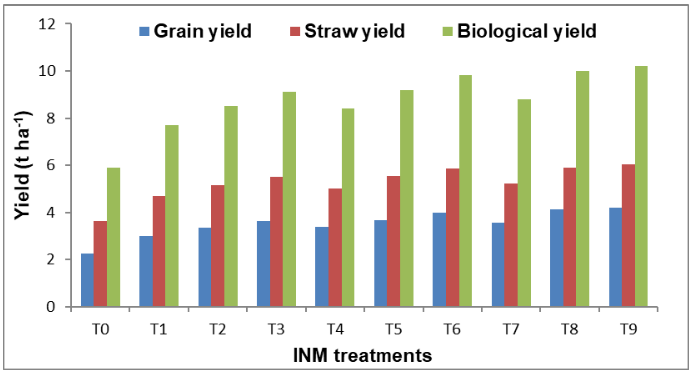

Fig. 1. Effect of integrated nutrient management on grain, straw and biological yield of wheat (t ha^{-1})

Table 1. Effect of integrated nutrient treatments on dry matter accumulation, CGR and RGR of wheat (Pooled mean of two years)

Treatments	DMA				CGR				RGR		
	30 DAS	60 DAS	90 DAS	At harvest	0-30 DAS	30-60 DAS	60-90 DAS	90-At harvest	30-60 DAS	60-90 DAS	90 DAS-harvest
INM in wheat											
Control	23.15	44.41	79.17	100.1	0.77	0.71	1.16	0.70	1.60	1.84	1.94
50% RDF	23.11	47.68	83.52	104.6	0.77	0.82	1.19	0.70	1.63	1.87	1.96
75% RDF	24.11	49.19	87.78	114.0	0.80	0.84	1.29	0.88	1.65	1.89	1.99
100% RDF	25.43	50.60	91.85	121.4	0.85	0.84	1.38	0.98	1.66	1.91	2.02
50% RDF+FYM 5 t/ha	24.04	49.15	89.26	117.0	0.80	0.84	1.34	0.93	1.65	1.89	2.00
75% RDF+FYM 5 t/ha	25.39	50.86	95.31	126.0	0.85	0.85	1.48	1.02	1.66	1.92	2.03
100% RDF+FYM 5 t/ha	26.34	51.57	100.89	130.0	0.88	0.84	1.64	0.97	1.66	1.95	2.05
50% RDF+FYM 5 t/ha+ *Azotobacter*+PSB	24.73	49.54	93.78	118.3	0.82	0.83	1.47	0.82	1.65	1.92	2.01
75% RDF+FYM 5 t/ha+ *Azotobacter*+PSB	25.89	51.92	101.61	132.9	0.86	0.87	1.66	1.04	1.67	1.95	2.06
100% RDF+FYM 5 t/ha+*Azotobacter* +PSB	26.52	53.09	104.12	134.3	0.88	0.89	1.70	1.01	1.68	1.96	2.06
SEm±	1.21	0.56	1.16	1.54	0.04	0.05	0.05	0.06	0.01	0.01	0.01
CD (P=0.05)	NS	1.61	3.33	4.42	0.12	0.14	0.13	0.18	0.01	0.01	0.02

DAS=Days after sowing, RDF=Recommended dose of fertilizer, FYM=Farm yard manure and PSB= Phosphate Solubilizing Bacteria, 100% RDF for wheat; 120 N: 40 P_2O_5: 20 K_2O, CGR= Crop Growth Rate, RGR= Relative Growth Rate, DMA= Dry Matter Accumulation

Table 2. Effect of integrated nutrient treatments on growth (chlorophyll content, total tillers) & yield attributes (Effective tillers, test weight) and yield of wheat (Pooled mean of two years data)

Treatments	Chl a (mg g^{-1} of fresh leaves)	Chl b (mg g^{-1} of fresh leaves)	Total Chl (mg g^{-1} of fresh leaves)	Total tillers at harvest m^{-1} row length (no.)	Effective tillers m^{-1} row length (no.)	Test Weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
INM in wheat								
Control	0.85	0.62	1.46	78.36	69.08	35.25	2.25	3.64
50% RDF	0.99	0.71	1.70	90.23	81.03	35.66	2.99	4.70
75% RDF	1.04	0.75	1.79	97.57	89.32	35.83	3.35	5.16
100% RDF	1.08	0.79	1.87	102.72	92.42	36.15	3.63	5.49
50% RDF + FYM 5 t/ha	1.05	0.74	1.78	94.01	84.85	36.45	3.37	5.02
75% RDF + FYM 5 t/ha	1.03	0.77	1.80	99.47	91.96	37.22	3.65	5.55
100% RDF + FYM 5 t/ha	1.13	0.81	1.94	103.47	95.94	37.57	3.98	5.86
50% RDF + FYM 5 t/ha + *Azotobacter* + PSB	1.07	0.75	1.82	95.32	86.94	37.05	3.57	5.21
75% RDF + FYM 5 t/ha + *Azotobacter* + PSB	1.15	0.85	2.01	104.00	96.38	37.45	4.12	5.89
100% RDF + FYM 5 t/ha + *Azotobacter* + PSB	1.18	0.88	2.06	104.92	98.52	38.01	4.18	6.03
SEm±	0.02	0.02	0.03	0.96	0.93	1.16	0.10	0.08
CD (P=0.05)	0.07	0.05	0.08	2.76	2.66	NS	0.29	0.22

DAS=Days after sowing, RDF=Recommended dose of fertilizer, FYM=Farm yard manure and PSB= Phosphate Solubilizing Bacteria, 100% RDF for wheat; 120 N: 40 P_2O_5: 20 K_2O

Table 3. Effect of integrated nutrient treatments on N, P, K content and protein content of wheat (Pooled mean of two years)

Treatments	Nitrogen content (%)		Phosphorous content (%)		Potassium content (%)		Protein content (%)
	Grain	Straw	Grain	Straw	Grain	Straw	Grain
INM in wheat							
Control	1.49	0.57	0.416	0.204	0.47	1.17	9.33
50% RDF	1.55	0.62	0.450	0.208	0.49	1.17	9.66
75% RDF	1.61	0.65	0.477	0.214	0.49	1.19	10.04
100% RDF	1.70	0.69	0.507	0.221	0.50	1.20	10.63
50% RDF+FYM 5 t/ha	1.59	0.63	0.469	0.209	0.49	1.20	9.92
75% RDF+FYM 5 t/ha	1.69	0.68	0.510	0.222	0.50	1.23	10.54
100% RDF+FYM 5t/ha	1.77	0.74	0.523	0.230	0.51	1.27	11.06
50% RDF+FYM 5 t/ha+*Azotobacter*+PSB	1.60	0.65	0.481	0.211	0.50	1.23	10.02
75% RDF+FYM 5 t/ha+*Azotobacter*+PSB	1.78	0.74	0.526	0.231	0.51	1.28	11.14
100% RDF+FYM 5 t/ha+*Azotobacter*+PSB	1.81	0.76	0.534	0.238	0.52	1.29	11.29
SEm±	0.02	0.01	0.005	0.003	0.02	0.04	0.11
CD (P=0.05)	0.05	0.03	0.014	0.009	NS	NS	0.32

DAS=Days after sowing, RDF=Recommended dose of fertilizer, FYM=Farm yard manure and PSB= Phosphate Solubilizing Bacteria, 100% RDF for wheat; 120 N: 40 P_2O_5: 20 K_2O

The presence of plant growth-promoting substances such as plant growth hormones and humic acids in FYM has been suggested as a possible factor contributed to increased yield [33]. Bahadur et al. [34] reported that PSB solubilize the unavailable phosphate in available form and *Azotobacter* fixed the free environmental nitrogen in soil, which increased the grain yield of wheat [35]. Significant increase in straw yield (Table 2) due to integrated nutrients of FYM, fertilizer and biofertilizers application might be due to its direct influence on dry matter production of each vegetative part and indirectly through increased morphological parameters of growth like plant height and tillering [12]. In Fig. 1, pooled mean data of two years of grain, straw and biological yield is shown.

3.3 Nutrient Content of Wheat

Quality of wheat as nutrient content of N, P and K both in grain and straw and protein content in grain of wheat crop increased significantly with the application of 75% RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB and found at par with 100% RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB and 100% RDF+5t FYM during both years and in pooled analysis (Table 3). But uptake of nutrients was at par with 100% RDF+5 t FYM ha^{-1}+*Azotobacter*+PSB only, Chauhan et al. [30] also supported the findings. This might be because of improved nutritional environment in the rhizosphere as well as in the plant system, leading to enhanced translocation of N, P and K in plant parts [36]. Recommended dose of fertilizer enhanced efficiency of nutrients, thus maintained synergistic interaction. Further, it might be the synergetic effect of organic manure and biofertilizers on nutrient availability and soil health for root development and absorption of nutrients. The contribution of organic manure and biofertilizers improves soil physical properties, which impart better environment for root growth, thereby creates more absorptive surface for uptake of nutrients as revealed by Verma et al. [37].

Increased grain and straw yield coupled with higher nutrient (Nitrogen, phosphorus and potassium) and protein content in plant seemed to have the increased uptake of nitrogen, phosphorus and potassium by the crop due to different treatments. The uptake of nutrients is a function of biomass production and nutrient concentration [38]. Thus, increase in concentration and biomass increase the uptake of nutrients. These results are in the line with the findings of other authors in several studies [39,40,41] who also reported improved nutrient content by application of organic manure. Sharma et al. [25] reported that the inoculation of seeds with phosphate solubilizing microorganisms significantly increased the uptake of nitrogen which may be due to enhanced availability and uptake of phosphorous, which is known to be positively related with uptake of nitrogen.

4. CONCLUSION

Based on the two years of study it is concluded that addition of 75% RDF + 5t FYM + *Azotobacter* + PSB in wheat gave significantly higher growth and yield attributes, grain and straw yields, nutrient content and uptake of wheat which was statistically at par with 100% RDF (120 kg N-40 kg P_2O_5-20 K_2O ha^{-1}) + 5t FYM + *Azotobacter* + PSB. Thus, for better nutrient management and for obtaining higher yields and nutrient content of crop 75% RDF+5 t FYM+*Azotobacter*+PSB in wheat should be applied throughout the *rabi* season, as there is saving of 25% of nutrients compared to 100 % RDF along with FYM and biofertilizer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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