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Effect of different sources of nutrients on growth and productivity of maize-wheat cropping system under rainfed conditions

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Abstract

A field experiment was conducted for four consecutive seasons from *kharif* 2019 to *rabi* 2020-21 at CSK, Himachal Pradesh, Krishi Vishvavidyalaya, Palampur, Himachal Pradesh (India) to evaluate the effect of different sources of nutrients on growth and productivity of maize-wheat cropping system. The experiment was laid down in Randomized Block Design with three replications having seven treatments *viz*., T_1- 10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval, T_2- 10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval, T_3- 50% RDN+ 10 t ha^{-1} FYM+ 5% *Jeevamrit* as basal and at 4 weeks interval, T_4- 50% RDN+ 10 t ha^{-1} FYM+ 10% *Jeevamrit* as basal and at 4 weeks interval T_5- seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval, T_6- seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval, T_7- recommended NPK through inorganic sources. Application of 50% RDN + 10 t ha^{-1}FYM + 10% *Jeevamrit* remaining at par with application of 50% RDN + 10 t ha^{-1} FYM + 5% *Jeevamrit* and application of recommended NPK resulted in higher leaf area index and crop growth rate of maize and wheat. Application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* proved best to obtain higher relative growth rate of maize, whereas relative growth rate of wheat at 60-90 DAS, 90-120 DAS and 120-150 DAS was significantly higher with *Beejamrit* + 5% *Jeevamrit* application. Significantly higher grain yield of maize and wheat, total yield of system and system productivity of maize-wheat cropping system was obtained with 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit*.

Key words: Leaf area index, *Jeevamrit*, yield, maize, wheat.

Maize-wheat is the third most important cropping system of India (Sharma *et al.* 2020) and ranks first under rainfed conditions as it contributes 3% in Indian food grain production (Faujdar ad Sharma 2013). Maize and wheat occupy 9.90 and 30.60 million hectares in India with total production of 31.65 and 109.59 million tonnes, respectively (Anonymous 2021a). While in Himachal Pradesh, maize-wheat is most important cropping system having acreage of 0.205 and 0.330 million hectares, respectively and contributes 85.62% to total food grain production (Anonymous 2021b). Nutrient management can take key part to sustain the productivity of maize wheat cropping as maize and wheat are versatile crops having great yield potential under diverse ecological conditions (Joshi *et al.* 2013; Sharma *et al.* 2020) but being nutrient exhaustive crops, both crops need enormous amount of nutrients to maintain its productivity; however, both crops respond well to applied nutrients. Rise in cost of chemical fertilizers and atmospheric pollution, soil degradation with their indiscriminate use strengthens the call of substitution of chemical fertilizer with renewable sources of nutrition. Organic nutrient management can be a viable option to counter these ill effects but organic manures alone are not able to produce required food grain. Hence, to maintain ecological balance and sustain crop yield for prolonged periods integrated nutrient management approach, using both chemical and organic manures would need to be adopted (Bajpai *et al*. 2006). Organic manures improve soil organic matter thus improves soil properties such as soil pH, cation exchange capacity and bulk density which helps to retain nutrients in soil solution and make them available to plants (Diacono and Montemurro 2010). Further, integration of organics and in organics results in better utilization of soil moisture and available nutrients leading to better root growth of plants (Bandopadhyay *et al*. 2003). In present scenarios, maximum use of organic manures including liquid manures *i.e*., *Beejamrit* and *Jeevamrit* while reduces the use of chemical fertilizers has become issue of prime importance for obtaining better growth and productivity of maize-wheat cropping system. Therefore, organic manures and inorganic manures have to give adequate attention. Keeping the above points into consideration present study was conducted to evaluate the response of different combination of nutrients on the growth and productivity of maize wheat cropping system.

Materials and Methods

An experiment was conducted at Fodder Farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh (India) from *kharif* 2019 to *rabi* 2020-21to evaluate the effect of different sources of nutrients on growth and productivity of maize-wheat cropping system. Geographically, the experimental site was located at 32^{o} 6' N latitude and 76^{o} 3' longitude at an elevation of 1290.8 m above mean sea level in North-Western Himalayas. Agro-climatically experimental site falls under sub-temperate and sub-humid zone, characterized by high annual rainfall (2200-2500 mm) with mild summers (19-31 ^{o}C) and extreme winters (3.5-1.4 ^{o}C). The soil of the experimental field was silty clay loam in texture; acidic in reaction (pH 5.45); high in organic carbon (7.9 gkg^{-1}); low in available nitrogen (236 kgha^{-1}); medium in available phosphorus (16 kg ha^{-1}) and potassium (167 kg ha^{-1}). The experiment was laid out in a Randomized Block Design with three replications and comprised of seven treatments *viz*., T_1- 10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval, T_2- 10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval, T_3- 50% recommended dose of N + 10 t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval + 100% recommended of P and K, T_4- 50% recommended dose of N + 10 t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval+ 100% recommended of P and K, T_5- seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval, T_6- seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval and T_7-recommended NPK through inorganic sources. During each season 15 days prior to sowing, whole quantity of FYM was applied on dry weight basis and then incorporated into the soil in all the treatments comprising of FYM application (T_1-T_4). Recommended dose of NPK for maize and wheat were 120, 60 and 40 kg ha^{-1} and 120, 60 and 30 kg ha^{-1}, respectively, which was applied in T_7 through urea, single super phosphate and muriate of potash. For both the crops in each season, half dose of N in T_1, T_2 and T_7 and whole of P and K were applied at the time of sowing and remaining half dose of N was top dressed after 30 days of sowing of both the crops. Seed of both the crops were treated with *Beejamrit* a night prior to sowing in each season for T_5 and T_6. Two dilutions of 5% and 10% from the concentrated *Jeevamrit* were prepared and applied at the rate of 500 l ha^{-1}as basal and then 4 weeks interval for both the crops in T_1 to T_6 from sowing to harvesting of crop. *Jeevamrit* was applied five time in *kharif* 2019 and four time in *kharif* 2020 and seven times in both the rabi seasons. Maize crop was sown on 6th June and 11th June during *kharif* 2019 and *kharif* 2020, whereas wheat was sown on 11th November and 19th November during *rabi* 2019-20 and *rabi* 2020-21, respectively. MM-2255 hybrid of maize at a spacing of 60 cm x 20 cm and HPW 236 cultivar of wheat at 20 cm row to row spacing were sown in 4.8 m x 3 m (14.4 m^{2}) plots. Growth parameters such as leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were determined at 30 days interval for both the crops. LAI was calculated using formula described by Dugje and Odo (2006):

$$LAI = \frac{P \times L \times A}{10^7}$$

Where: P= plant population ha^{-1}, L = number of fully expanded leaves plant^{-1}and A= single leaf area (cm^{2}).

The CGR (Radford 1967), RGR (Blackman 1919) and system productivity were calculated by following methods:

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}$$

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1}$$

Where:

W_1 & W_2 : Total dry weight (g) of plant at time T_1 and T_2

$T_2 - T_1$: Time interval (days) between two dates of observation

The effects of treatments were same during both the years and data of various parameters were statistically analyzed following the standard analysis of the variance technique (ANOVA) as described by Gomez and Gomez (1984).

Results and Discussion

Leaf area index

Data on LAI of maize and wheat have been presented in Table 1. Irrespective of the treatments, LAI of maize and wheat, in general, increased up to 90 and 120 DAS, respectively. On mean basis, in both the crops, combined application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_4) resulted in significantly higher LAI at all the observational stages of maize and at 120 DAS and 150 DAS of wheat, although it remained at par with combined application of 50% RDN + 10 t ha^{-1}FYM +5% *Jeevamrit* (T_3) and recommended NPK (T_7), while data on LAI of wheat further indicated that different nutrient management practices did not influence LAI of wheat significantly upto 90 DAS. Significantly lower LAI of both crops was observed with *Beejamrit* + 5% *Jeevamrit* application (T_5). Higher LAI of maize and wheat obtained with integrated nutrient management *i.e.*, 50% RDN + 10 t ha^{-1}FYM+10% *Jeevamrit* (T_4) might be attributed to production of higher number of leaves, more number of plants per unit area and increased leaf area, consequently higher LAI. Balanced application of nutrients at higher rate through integrated nutrient management provided nutrients for longer time during crop growth period affected LAI favourably. The beneficial effect of farm yard manure application on LAI might be due to synthesis of certain phytohormones and vitamins and more interception of solar radiation and synthesis of more chlorophyll which resulted in higher LAI in maize (Ponmozhi *et al*. 2019). Maqsood *et al*. (2005) reported the highest LAI with the application of 125 kg N ha^{-1}. Similarly, higher LAI was obtained with higher level of nitrogen in different crops (Murthy *et al*. 2012 and Gungula *et al*.

Table 1. Effect of nutrient management on periodic leaf area index of maize and wheat

Treatment	Maize			Wheat				
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1-10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval	0.46	3.13	4.25	0.19	1.05	2.85	3.11	2.49
T_2-10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval	0.51	3.57	4.64	0.22	1.08	3.03	3.38	2.75
T_3-50% of recommended N+ 10 t ha^{-1} FYM+ 5% *Jeevamrit* as basal and at 4 weeks interval	0.62	5.17	6.37	0.24	1.23	3.62	4.14	3.38
T_4-50% of recommended N+ 10 t ha^{-1} FYM+ 10% *Jeevamrit* as basal and at 4 weeks interval	0.64	5.38	6.75	0.27	1.38	3.93	4.62	3.72
T_5-Seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval	0.39	2.09	3.72	0.19	0.76	1.98	2.15	1.71
T_6-Seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval	0.46	2.39	4.25	0.20	0.90	2.39	2.64	2.16
T_7-Recommended NPK through inorganic sources	0.62	5.15	6.30	0.23	1.19	3.44	3.86	3.19
SEm ±	0.03	0.24	0.36	0.02	0.14	0.40	0.45	0.35
CD (P=0.05)	0.08	0.74	1.10	NS	NS	NS	1.38	1.08

2015). Dugje and Odo (2006) established direct relationship of LAI with number of leaves and leaf area.

Crop growth rate

The data presented in Table 2 clearly indicated that CGR varied significantly among different treatments. The data revealed that CGR consistently increased upto 30-60 DAS in maize and 90-120 DAS in wheat and, then decreased till harvesting. On mean basis, in both the crops, application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_4) remained statistically at par with application of 50% RDN + 10 t ha^{-1} + 5% *Jeevamrit* (T_3) and recommended NPK (T_7) but all these treatments resulted in significantly higher CGR of maize and wheat at all the observational stages except at 150-harvest in wheat. Higher CGR with integrated nutrient management can be attributed to better growth of the crops in respective treatments. The release of nutrients from the mineralization of added FYM as well as nitrogen fixation by microbes due to application of *Jeevamrit* throughout the crop season might have resulted in better nutrient availability to the crop, better soil moisture availability under organic manuring, hence subsequently higher dry matter accumulation (Kumar *et al*. 2021). Ponmozhi *et al*. (2019) reported maximum plant height, leaf area, dry matter accumulation and consequently CGR of maize with integrated application of chemical fertilizers and organic manures. CGR increased consistently and attained maximum values at 30-60 DAS in maize and 90-120 DAS in wheat. In general,CGR in the early stages was lower due to the slower vegetation growth and low percentage of light absorption, but with the rapid increases in the rate of plant growth resulted in higher dry matter production which might be attributed to better development of leaves (expansion and stomata numbers) and plant canopy results in higher absorption of solar radiation by plants and higher photosynthesis (Song *et al*. 2013 and Evan 2013).

Table 2. Effect of nutrient management on periodic crop growth rate (g m^{-2} day^{-1}) of maize and wheat

Treatment	Maize			Wheat				
	30-60 DAS	60-90 DAS	90-Harvest	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150-Harvest
T_1-10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval	11.8	5.7	1.5	2.29	8.97	11.59	3.34	0.87
T_2-10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval	11.6	6.3	1.7	2.32	9.25	11.99	3.65	0.65
T_3-50% of recommended N+ 10 t ha^{-1} FYM+ 5% *Jeevamrit* as basal and at 4 weeks interval	14.8	8.4	2.1	2.79	11.88	14.53	5.78	1.14
T_4-50% of recommended N+ 10 t ha^{-1} FYM+ 10% *Jeevamrit* as basal and at 4 weeks interval	14.9	8.6	2.4	2.95	12.00	15.04	5.55	1.26
T_5-Seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval	7.9	3.4	1.2	1.10	6.05	8.55	4.05	0.49
T_6-Seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval	8.9	3.3	1.6	1.28	6.17	9.09	4.05	0.52
T_7-Recommended NPK through inorganic sources	14.6	8.5	2.2	2.73	11.36	14.61	5.02	1.21
SEm ±	0.6	0.6	0.1	0.10	0.22	0.26	0.43	0.29
CD (P=0.05)	1.9	1.9	0.4	0.31	0.65	0.80	1.34	NS

Relative growth rate

The data on RGR summarized in Table 3 indicated that RGR consistently decreased from 30-60DAS to harvest in both maize and wheat. Application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_4) found statistically similar to application of 50% RDN + 10 t ha^{-1} FYM + 5% *Jeevamrit* (T_3) and recommended NPK (T_7) resulted in significantly higher RGR of maize at 60-90 DAS, while data on RGR of wheat indicated significant variations under different treatments at 60-90 DAS and 120-150 DAS. Applicationof *Beejamrit* + 5% *Jeevamrit* (T_5) remained statistically at par with *Beejamrit* + 10% *Jeevamrit* (T_6) and resulted in significantly higher RGR of wheat at 60-90 DAS, 90-120 DAS and 120-150 DAS. Dry matter accumulation also attributes to RGR, hence, higher dry matter accumulation on existing dry matter resulted in higher RGR. Better nutrition of the crop in all the treatments of integrated and inorganic nutrient management resulted in better plant height and shoot number and dry matter accumulation, consequently resulted in higher RGR. Singh *et al*. (2018) also obtained better dry matter accumulation of wheat with the integrated and inorganic nutrient management practices which was ascribed to more availability of nutrients in soil and their assimilation by plants (Verma *et al*. 2012).

Productivity

The data on grain yield and system productivity of maize wheat cropping system in Table 4 indicated superiority of integrated nutrient management treatments over organic nutrient management practices and application of natural farming components *i.e*., *Beejamrit* and *Jeevamrit*. On mean basis, application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_4) remaining at par with the application of 50% RDN + 10 t ha^{-1} FYM + 5% *Jeevamrit* (T_3) and recommended NPK application (T_7) resulted in significantly higher grain yield of maize and wheat and system productivity of maize-wheat cropping system. On mean basis, application of 50% RDN + 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_4) produced 6.81%, 33.77%, 41.18%, 93.36% and 117.02% higher maize grain yield and 6.57%, 33.12%, 43.54%, 73.66% and 90.09% higher wheat grain yield over application of recommended NPK (T_7), 10 t ha^{-1} FYM + 10% *Jeevamrit* (T_2), 10 t ha^{-1} FYM + 5% *Jeevamrit* (T_1), *Beejamrit* + 10% *Jeevamrit* (T_6) and *Beejamrit* + 5% *Jeevamrit* (T_5), respectively. Integrated nutrient management practices performed better than organic nutrient management and application of natural farming components might have maintained higher nitrogen availability to crops as microbial load

Table 3. Effect of nutrient management onperiodic relative growth rate (mg g^{-1} day^{-1}) of maize and wheat

Treatment	Maize			Wheat				
	30-60 DAS	60-90 DAS	90-Harvest	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150-Harvest
T_1-10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval	33.2	8.9	2.0	60.7	48.6	22.9	4.5	1.1
T_2-10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval	31.9	9.5	2.2	58.5	48.6	23.0	4.7	0.8
T_3-50% of recommended N+ 10 t ha^{-1} FYM+ 5% *Jeevamrit* as basal and at 4 weeks interval	34.3	10.4	2.2	56.5	49.9	22.3	5.9	1.0
T_4-50% of recommended N+ 10 t ha^{-1} FYM+ 10% *Jeevamrit* as basal and at 4 weeks interval	33.7	10.5	2.4	56.5	48.8	22.5	5.5	1.1
T_5-Seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval	30.1	7.3	2.4	50.1	55.4	25.8	7.5	0.8
T_6-Seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval	31.3	6.7	2.9	49.9	51.8	25.4	7.1	0.8
T_7-Recommended NPK through inorganic sources	34.5	10.6	2.3	56.8	49.4	23.0	5.3	1.2
SEm ±	1.5	0.9	0.2	2.5	0.9	0.7	0.6	0.3
CD (P=0.05)	NS	2.8	NS	NS	2.7	2.2	1.8	NS

Table 4. **Effect of nutrient management on grain yield (t ha^{-1}), total yield of system (t ha^{-1}) and system productivity (kg ha^{-1} day^{-1}) of maize-wheat cropping system**

Treatment	Grain yield		Total yield of system	System productivity
	Maize	Wheat		
T_1-10t ha^{-1} FYM + 5% *Jeevamrit* as basal and at 4 weeks interval	2.89	2.94	5.83	19.59
T_2-10t ha^{-1} FYM + 10% *Jeevamrit* as basal and at 4 weeks interval	3.05	3.17	6.22	20.89
T_3-50% of recommended N+ 10 t ha^{-1} FYM+ 5% *Jeevamrit* as basal and at 4 weeks interval	3.97	4.08	8.05	27.06
T_4-50% of recommended N+ 10 t ha^{-1} FYM+ 10% *Jeevamrit* as basal and at 4 weeks interval	4.08	4.22	8.31	27.92
T_5-Seed treatment with *Beejamrit* followed by 5% *Jeevamrit* as basal and at 4 weeks interval	1.88	2.22	4.10	13.76
T_6-Seed treatment with *Beejamrit* followed by 10% *Jeevamrit* as basal and at 4 weeks interval	2.11	2.43	4.54	15.25
T_7-Recommended NPK through inorganic sources	3.82	3.96	7.78	26.13
SEm ±	0.17	0.14	0.22	0.74

application through *Jeevamrit* mineralized native pools of nitrogen and reduces nitrogen losses. Generally, application of nitrogen through inorganic sources makes nutrients readily available to plants however, it is also vulnerable to leaching and volatilization losses, while application of organic matter in the form of crop residue *i.e.*, root decaying and decomposition of leaf litter during growing period and FYM application enhances soil organic carbon content in soil (Jarecki and Lal 2003) and more organic carbon content in soil reduces these losses and improves soil health and tilth (Chandra *et al*. 2004 and Khalofah *et al*. 2021). Moreover, FYM improves water holding capacity and microbial activity and soil quality as well (Chandra *et al*. 2004) which was ultimately reflected into crop grain yield of crops and system productivity. Sharma *et al*. (2020) also observed higher grain yield of maize-wheat cropping system under rainfed conditions of Punjab. Beneficial effect of integration of organics and inorganics was also observed by Basak *et al*. (2013); Bharti and Sharma (2013); Durani *et al*. (2017). The data further advocated significant difference in organic nutrient management treatments and application of natural farming components *vis-à-vis* grain yield of maize and wheat, total yield of system and system productivity of maize-wheat cropping system. Application of 10 t ha^{-1} + 10% *Jeevamrit* (T_2) increased maize grain yield to the tune of 44.52% to 62.23% and wheat grain yield to the tune of 30.45% and 42.79% over application of *Beejamrit* and 10% *Jeevamrit* (T_6) and *Beejamrit* + 5% *Jeevamrit* (T_5), respectively, while this magnitude of increase was 36.97% to53.72% and 20.99% to 32.43% with the application of 10 t ha^{-1} + 5% *Jeevamrit* (T_1) over respective treatments. The data clearly advocated benefits of organic manures besides application of nitrogen, phosphorus and potassium, it improves microbial activities, better supply of macro and micro nutrients *viz*., sulphur, zinc, copper, boron which are not supplied in sufficient amount by application of natural farming components and reduces nutrient losses (Yadav *et al*. 2000). The higher maize yield obtained in FYM amended plots might be associated with better supply pattern of nutrients and improved soil properties (Singh *et al*. 2004). Beneficial effect of organic nutreint management on economic yield of crops was also reported by Lotter (2003); Choudhary and Kumar 2013; Dhiman and Dubey (2017).

Conclusively, integration of different sources of nutrients has favourable effect on growth and productivity of maize-wheat cropping system in terms of grain yield of maize and wheat, total yield of system and system productivity of maize-wheat cropping system. To obtained higher LAI and CGR at different stages of crop growth, application 50% RDN + 10 t ha^{-1} FYM and *Jeevamrit* (5% and 10%) and recommended NPK proved best over other treatments.

Conflict of interest: The authors declare that there is no conflict of interest.

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