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Impact of foliar application of bio nano P and K and their conventional sources on yield of maize and wheat in an acid *Alfisol*

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Abstract

To assess the effectiveness of bio-nano P and K fertilizer solutions in optimizing respective nutrient requirement in maize-wheat sequence, a field experiment was conducted in an acid *Alfisol* during 2019-20 at the experimental farm of CSKHPKV, Palampur in a randomized block design comprising fourteen treatments. Specifically, the experiment aimed at evaluating the efficacy of two foliar applications of bio nano P and K (one 30-35 days after germination of crop and second 20-25 days after first spray) in comparison to their conventional sources at 0, 50 and 100 per cent RDF levels of P and K individually and also in combination with 50 and 100 per cent RDF levels of P & K on productivity in maize and wheat crops. Highest grain (52.9 and 33.4 q ha^{-1}) and stover/straw yield (82.1 and 49.4 q ha^{-1}) of maize and wheat, respectively, were observed with treatment where 100 per cent RDF was applied through conventional sources along with two foliar applications of bio nano P and K (T_{13}) whereas lowest grain (19.6 and 16.6 q ha^{-1}) and stover/ straw yield (30.0 and 28.1 q ha^{-1}) was observed with natural farming treatment (T_{14}). The treatments P_{50} (T_2) and P_0 + BN-P (T_4), P_{100} (T_3) and P_{50} + BN-P (T_5) in case of P and K_{50} (T_8) and K_0 + BN-K (T_9) and K_{100} (T_3) and K_{50} +BN-K (T_{10}) were statistically at par with each other. Similarly, treatments P_{100} K_{100} (T_3) and P_{50} K_{50} + BN-P & K (T_{12}) showed statistical similarity, highlighting the effectiveness of foliar bio nano application in optimizing crop nutrient requirement to the extent of 50 per cent of the RDF.

Key words: Maize, wheat, bio nano P, bio nano K, natural farming, yield, Alfisol

Agriculture has played an important role in the economic development of agrarian India with more than 50 per cent of the population depending on it. The all India food grain production has increased from 175 million ton in 2002 – 2003 to 296 million ton in 2019 – 2020 (Casey 2020). With only a marginal increase in acreage, the increase in the productivity levels plays a vital role in the growth of the agriculture industry. However, while India has the largest area of arable and permanently cropped land in the world, it ranks third in the world in overall food grain production after China and the US, primarily due to low crop productivity. With limited arable land and rising food needs, the long-term potential for increase in fertilizer usage is moderately high in India. 30-40 per cent of crop productivity depends upon fertilizers but some fertilizers affect the plant growth directly.

After nitrogen, phosphorus and potassium are the two nutrient elements which limit crop productivity worldwide especially in low input systems (Wang *et al*. 2013; Cong *et al*. 2020). Phosphorus controls mainly the reproductive growth of plants (Wojnowska *et al*. 1995) and is the second most crop-limiting nutrient in most of the soils. Potassium (K) is a primary osmoticum in maintaining low water potential in plant tissues. It plays a vital role in protein synthesis, enzyme activation, photosynthesis and regulation of plant stomata, translocation of photosynthates and many other processes (Reddya *et al*. 2004).

The overall fertilizer consumption in India has grown from 50.6 million ton in 2009 to 61.4 million ton in 2020. However total fertilizer production in India during 2020 was 42.21 million tonnes, out of which phosphorus production contributed 4.65

million tonnes, and potassium was completely imported (Casey, 2020). India is meeting 80% of its urea requirement through indigenous production but is largely dependent on import for phosphatic and potassic fertilizers. During 2021-22, 17.4, 40.1 and 59.6 lakh metric tonnes of urea, DAP and MOP were imported, respectively. In India, maize and wheat consume 11 and 24% of total fertilizers consumption (Usama and Khalid 2018). The acreage under maize and wheat in Himachal Pradesh is 287 and 319 thousand hectares with a total production of 726 and 565 thousand million tonnes, respectively (Anonymous 2020). Both maize and wheat are fertilizer responsive crop and exhibit full yield potential when supplied with adequate quantity of nutrients at critical growth stages.

Nanotechnology offers great potential to produce nano fertilizers with the desired chemical composition, more nutrient use efficiencies and higher soil productivity. Bio-synthesized nano-nutrients (bio-nano nutrients) are relatively more stable and eco-friendly (Fatima *et al*. 2020). Nano fertilizers deal with the elements in nano meter dimensions (1–100 nm). At nano scale, these fertilizers release the nutrients at a slower rate for a longer period, consequently, limiting nutrients' losses from the soil and reducing groundwater pollution (Meena *et al*. 2017). Nano-fertilizers have an important role in the physiological and biochemical processes of crops by increasing the availability of nutrients, which help in enhancing metabolic processes and promoting meristematic activities causing higher apical growth and photosynthetic area (De Rosa *et al*. 2010). Nano particles have unique physico-chemical properties and key potential to boost the plant metabolism (Zulfiqar *et al*. 2019; Raliya *et al*. 2018). The use of nano-fertilizers instead of conventional synthetic fertilizers is a way to release nutrients into soil in controlled and conditional way, thus, reducing the loss of nutrients, soil toxicity and maintain sustainability and protection of agricultural produce (Arif *et al*. 2016).

No doubt increased use of chemical fertilizers helped in enhancing production and productivity of maize and wheat crops but at the same time has caused reduction in fertilizer use efficiency of crops (Abbasi *et al*. 2013, Meng *et al*. 2016 & Ahmed *et al*. 2017). Nano fertilizer exploit the porous nano scale part of the plant and could reduce nutrients' loss by promoting enhanced plant nutrient uptake (Tarafdar *et al*. 2013). IFFCO has developed nano- urea, bio-nano P and bio-nano K fertilizers. Recently, nano-urea has been recommended as an effective N fertilizer for different cropping systems of the country. As regards bio-nano P & K fertilizers, there is a need to investigate their effect on yield, nutrient uptake, soil health and economics in different cropping systems of the country. Hence, looking to the above facts, the present investigation was carried out in order to investigate the effect of nano fertilizers on crop productivity.

Materials and Methods

A field experiment was conducted on maize (Kanchan Gold) and wheat (HPW 236) in an acid *Alfisol* at the experimental farm of CSKHPKV, Palampur during *Kharif* 2019 and Rabi 2019-20 in a randomized block design (RBD) having a plot size of 12 m^2 (5m × 2.4m) comprising fourteen treatments replicated thrice *viz*., $N_{100}P_0K_{100}$ (T_1), $N_{100}P_{50}K_{100}$ (T_2), $N_{100}P_{100}K_{100}$ (T_3), $N_{100}P_0K_{100}$+ BNP (T_4), $N_{100}P_{50}K_{100}$ + BNP (T_5), $N_{100}P_{100}K_{100}$ + BNP (T_6), $N_{100}P_{100}K_0$ (T_7), $N_{100}P_{100}K_{50}$ (T_8), $N_{100}P_{100}K_0$ + BNK (T_9), $N_{100}P_{100}K_{50}$ + BNK (T_{10}), $N_{100}P_{100}K_{100}$ + BNK (T_{11}), $N_{100}P_{50}K_{50}$+ BNP & BNK (T_{12}), $N_{100}P_{100}K_{100}$+ BNP & BNK (T_{13}) and natural farming (T_{14}). The area received a mean annual rainfall of 2,750 mm with a mean maximum and minimum temperature of 22.05±5.25°C (in June) and 11.16±6.51°C (in December), respectively. Soil of the study area was silty clay loam in texture and was classified as "Typic Hapludalf". Basal application of recommended dose of phosphorus and potassium for maize (60 and 40 kg ha^{-1}, respectively) and wheat (60 and 30 kg ha^{-1}) was done through DAP and MOP. Besides, 10 t FYM ha^{-1} was applied to maize crop in all the treatments except natural farming. Two foliar sprays of bio nano P (40 ppm) and K (40 ppm) @ 40 mL L^{-1} were done at 30-35 days after germination of crop and 20-25 days after first spray.

Half dose of N and full doses of P_2O_5 and K_2O were applied at the time of sowing as per the treatment details. Remaining N was applied in two equal splits *i.e.* at knee high and pre-tasseling stages of maize and at crown root initiation (20-25 DAS) and tillering stages in wheat. Atrazine @ 1.125 kg ha^{-1} (as pre-emergence) in the maize crops and Vesta (Clodinafop

Propargyl 15% + Metsulfuron Methyl 1% WP @ 169 g acre^{-1} (as post-emergence) in the wheat crop (except in natural farming) were used for chemical weed control.

In natural farming treatment, application of *Ghanajeevamrita* was done @ 250 kg ha^{-1} and incorporated in the plots prior to sowing. Seeds were treated with *Beejamrita* @ 100 ml kg^{-1} seed before sowing. The seeds were mixed with *Beejamrita* using clean hands and all the seeds were coated uniformly. The coated seeds were spread on a plastic sheet in the shade and were allowed to dry for 2 to 3 hours. Application of *Jeevamrita* @ 500 litre ha^{-1} was done at the time of sowing followed by spray of *Jeevamrita* at an interval of 21 days. Mulching was done with locally available weeds (lantana) in maize and with maize stover in wheat crop @ 25t ha^{-1}.

The maize crop was sown on 29th June, 2019 and harvested on 28th October, 2019. The wheat crop was sown on 15th November, 2019 and harvested on 30th May, 2020. The wheat crop was irrigated at the crown root initiation, tillering, late jointing, flowering and dough stages. After harvesting and dehusking, the cobs they were air dried, shelled and weighed. Maize grain yield per plot was then recorded and the remaining plant material *i.e.* stalks were sun dried and weighed to determine the stover yield on dry weight basis. Wheat crop harvested from each plot, was dried and threshed. The grains were then cleaned and weighed. Straw yield of wheat was calculated by subtracting the grain yield from biological yield.

Results and Discussion

Effect of bio nano P and K and their conventional sources on maize grain and stover yield (q ha^{-1}) *Kharif* 2019

Table 1 depicted the effect of foliar application of bio nano P and K with and without their respective conventional sources on grain and stover yield of maize during *Kharif* 2019. A perusal of table 1 revealed that all the treatments had significant effect on maize yield. Maize grain yield ranged from 19.6 q ha^{-1} to 52.9 q ha^{-1}, registering lowest value for natural farming treatment (T_{14}) and highest for treatment where two foliar applications of bio nano P and K were done along with 100 per cent recommended dose of fertilizer (T_{13}).

A cursory glance at the data in respect of treatments T_1 to T_6 revealed significant increase in

Table 1. Effect of foliar application of bio nano P and K in conjunction with their conventional sources at different levels on grain and stover/straw yield (q ha^{-1}) of maize and wheat

Treatment (Symbol)	Maize 2019		Wheat 2019-20	
	Grain	Stover	Grain	Straw
$N_{100}P_0K_{100}$ (T_1)	35.3	51.9	25.2	35.0
$N_{100}P_{50}K_{100}$ (T_2)	41.0	61.5	28.2	39.8
$N_{100}P_{100}K_{100}$ (T_3)	46.3	69.9	30.6	44.4
$N_{100}P_0K_{100}$+ BNP (T_4)	42.6	62.6	29.0	40.9
$N_{100}P_{50}K_{100}$+ BNP (T_5)	47.9	71.8	31.2	44.6
$N_{100}P_{100}K_{100}$+ BNP (T_6)	50.2	77.8	32.8	47.6
$N_{100}P_{100}K_0$ (T_7)	41.2	56.8	27.3	38.8
$N_{100}P_{100}K_{50}$ (T_8)	44.2	67.3	29.1	41.0
$N_{100}P_{100}K_0$+ BNK (T_9)	45.4	67.4	30.4	42.5
$N_{100}P_{100}K_{50}$+ BNK (T_{10})	47.8	71.2	31.5	45.3
$N_{100}P_{100}K_{100}$ + BNK (T_{11})	48.9	76.8	32.2	47.7
$N_{100}P_{50}K_{50}$+BNP&BNK (T_{12})	47.8	70.8	31.6	45.2
$N_{100}P_{100}K_{100}$+BNP& BNK (T_{13})	52.9	82.1	33.4	49.4
Natural farming (T_{14})	19.6	30.0	16.6	28.1
CD (P=0.05)	1.6	4.3	1.0	1.6

BNP: Bio-nano P sprays, BNK: Bio-nano K sprays
100 per cent NPK application rate corresponds to the state level recommendation for respective nutrients (*i.e.* 120 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} to both maize and wheat and 40 and 30 kg K_2O ha^{-1} to maize and wheat, respectively).

maize grain yield, over the control treatment (T_1) with P, at 50 per cent and 100 per cent of recommended dose of P through conventional source alone or in conjunction with two foliar sprays of bio nano P. While comparing these treatments, statistical similarity was registered between treatments where 50 per cent recommended dose of P was applied through conventional source (T_2) and treatment where two foliar applications of bio nano P were done with no P application through conventional source (T_4) and also between the treatments where 100 per cent recommended dose of fertilizer was applied through conventional source (T_3) and two foliar applications of bio nano P along with 50 per cent of recommended dose of P through conventional source (T_5).

A similar trend was observed for the treatments pertaining to graded K levels with or without bio nano foliar application (T_3 & T_7 to T_{11}) where statistically similar results were obtained with treatments where 50 per cent recommended dose of K was applied through conventional source (T_7) and treatment where two foliar applications of bio nano K were done with no K application through conventional source (T_9) and also between the treatments where 100 per cent recommended dose of fertilizer was applied through conventional source (T_3) and two foliar applications of bio nano K along with 50 per cent of recommended dose of K through conventional source (T_{10}), indicating optimization of 50 per cent recommended dose of P and K through their conventional sources with two foliar applications of bio nano P and bio nano K fertilizers.

Further, two foliar applications of both bio nano P and K along with 50 per cent recommended dose of P and K through their conventional source (T_{12}) were found statistically at par with 100 per cent NPK (T_3) application, thereby indicating compatibility of bio nano P and K fertilizers with each other and 50% dose optimization.

The trend in case of maize stover yield was similar to that of maize grain yield. The stover yield varied from 30.0 q ha^{-1} in natural farming treatment (T_{14}) to 82.1 q ha^{-1}intreatment where two foliar applications of bio nano P and K were done along with 100 per cent NPK application through conventional source (T_{13}). The standard treatment i.e. 100 per cent NPK through conventional source showed statistical similarity with treatments where two foliar applications of bio nano P along with 50 percent of recommended dose of P through conventional source (T_5), two foliar applications of bio nano K along with 50 percent of recommended dose of K through conventional source (T_{10}) and two foliar applications of both bio nano P and K along with 50 per cent recommended dose of P and K through their conventional sources (T_{12}) was done, indicating 50 per cent dose optimization and compatibility of bio nano P and K with each other.

Effect of bio nano P and K and their conventional sources on wheat grain and straw yield (q ha^{-1}) during *Rabi* 2019-20

Data pertaining to grain and straw yield of wheat for *Rabi* 2019-20 have been presented in Table 1. Wheat grain and straw yield ranged from 16.6 q ha^{-1} and 28.1 q ha^{-1} in natural farming (T14) to 33.4 q $ha^{-1}$and 49.4 q ha^{-1} in treatment where 100 per cent NPK was applied through conventional source along with two foliar applications of bio nano P and K (T13), respectively. It is evident from the table that all the treatments significantly affected the wheat grain and straw yield. The standard treatment i.e. 100 per cent recommended dose of NPK through conventional source (T_3) was found to be statistically at par with treatments where two foliar applications of bio nano P along with 50 per cent of recommended dose of P through conventional source (T_5), two foliar applications of bio nano K along with 50 per cent of recommended dose of K through conventional source (T_{10}) and two foliar applications of both bio nano P and K along with 50 per cent recommended dose of P and K through their conventional sources (T_{12}) were applied which highlighted 50 per cent optimization of conventional fertilizers with two foliar applications of bio nano P and K. Further, statistical similarity of 100 per cent NPK (T_3) and 100 per cent N + 50 per cent PK + two foliar applications of bio nano P and K highlighted the compatibility of bio nano P and K fertilizers with each other.

On an average the increase in grain yield was 15.1, 10.6 and 7.2 per cent with two foliar applications of bio nano P along with their graded levels (0, 50 and 100%) through conventional sources (T_4, T_5 and T_6) in comparison to their corresponding conventional sources alone (T_1, T_2 and T_3), respectively. Likewise, 11.4, 8.3 and 5.2 per cent, respectively was recorded with two foliar applications of bio nano K along with their graded levels (0, 50 and 100 %) through conventional sources (T_9, T_{10} and T_{11}) in comparison to their corresponding conventional sources alone (T_7, T_8 and T_3). It is obvious that the increase was higher in P than K due to its physiological functions.

Similar trend was noticed in straw yield of wheat. Significantly high value of wheat straw yield was registered with treatment where 100 per cent recommended dose of fertilizer was added through conventional source along with two foliar applications of bio nano P and K (T_{13}) and significantly low straw yield was registered for natural farming treatment (T_{14}). Treatment where 100% NPK (T_3) was incorporated showed statistical similarity with treatments where 100 per cent NK + 50 per cent P +two foliar applications of bio nano P (T_5), 100 per cent NP + 50 per cent K +two foliar applications of bio nano K (T_{10}) and 100 per cent N + 50 per cent PK +two foliar applications of bio nano P and K (T_{12}) were applied.

Results obtained on the effect of P and K on grain and stover/straw yield of maize and wheat can be explained on the basis of their key functions as essential nutrients. The increase in grain and stover/straw yield with the application of phosphorus and potassium might be attributed to the source and sink relationship and translocation of photosynthates from source to sink which might have increased the yield. These results were in agreement with those of Sharma *et al*. (2018) and Sankadiya & Sanodiya (2021). The highest value of grain and stover/straw yield observed for treatment where 100 per cent NPK was applied along with two foliar applications of bio nano P and K (T_{13}) might be due to the fact that though P and K are required in large amounts in early growth stages however these are required by all the crops throughout the growth period and foliar application of nano P and K on account of their small size and large surface area might have resulted in acceptable reactivity leading to effective absorption of these nutrients for proper growth and plant metabolism and their slow release mechanism might have maintained the availability throughout the growth period thereby increasing the dry matter accumulation ultimately resulting in higher yields. Improved photosynthetic activity and plant growth with the application of nano fertilizers leading to improved yields have also been reported by Wu (2013) and Fatima *et al*. (2021). The present findings are within the close vicinity of those reported by Meena *et al*. (2020), Zain *et al*. (2015), Mer and Ama (2014), Drostkar *et al*. (2016), Abdel-Aziz *et al*. (2018), Sharar *et al*. (2003), Marzouk *et al*. (2019), Kogbe & Adediran (2003), Ekinci *et al*. (2014) and Liu & Lal (2014). Lowest value of yields recorded with natural farming treatment (T_{14}) might be attributed to the fact that at least five years are required to build up soil fertility for meeting out nutrient requirement of crop for better yields and maize and wheat being nutrient exhaustive crops their nutrient requirement for growth might not have met out.

Conclusion

From the present investigation it can be concluded that the conjoint use of conventional sources along with two foliar spray of bio nano P and K fertilizers recorded significantly higher crop yields over the use of conventional sources alone. Thus, nano- fertilizers can serve as an efficient nutrient delivery system thereby reducing the quantity of nutrients required. The conjoint use of bio nano P and K is advisable owing to their compatibility with each other. Keeping in view the results obtained from present study, two post emergence sprays of bio nano P and K saved 50 per cent of recommended dose of respective nutrient in maize wheat sequence and the findings may be of greater significance both from farm as well as national perspective.

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