__Original Research Article__

Foliar Application of Nano and Non-Nano Fertilizersand their Impact on Growth and Nutrient Use Efficiency of Indian Mustard [*Brassica Juncea* (L.) Czern&Coss]

ABSTRACT

An experiment was conducted during *rabi* 2020-21 at the SVPUA&T, Meerut, Uttar Pradesh, to study the Foliar application of nano and non-nano fertilizers and their impact on growth and nutrient use efficiency of Indian mustard [*Brassica juncea* (L.) Czern&Coss].The investigation was carried out in randomized block design with three replications and 12 treatments of nutrient management practices *viz.,* Control, N-P-K & S (120-40-40 & 20 kg/ha), 100% NPK & S + Zn 5 kg/ha, 100% NPK & S + Bio-stimulants, 100% NPK & S + Nano Zn, 75% NPK & S + NPK Consortia seed treatment, 75% NPK & S + Nano N, 75% NPK & S + Nano N + Nano Zn, 75% NPK & S + NPK Consortia seed treatment + Nano Zn, 75% NPKS + NPK (18:18:18), 75% NPKS + NPK (18:18:18) + Bio-stimulants and 75% NPK & S + Zn 5 kg/ha+ Bio-stimulants + Nano N + Nano Zn. The highest growth parameter *viz.,* plant height (216.16 cm), dry matter accumulation (102.7 g/plant) were recorded with treatment 100% NPK & S + Nano Zn whereas, the highest nutrient use efficiency was recorded with treatment 75% NPK & S + Zn 5 kg/ha+ Bio-stimulants + Nano N + Nano Zn.

Key words:Bio-stimulants, Nano fertilizers, NPK 18:18:18 and Nutrient use efficiency.

1.INTRODUCTION

Indian mustard is the thirdforemost edible oil seed crop in India. Globally, India holds the second place in area (8.20 M ha) and fourthplace in production (10.4 Mt) and producing an average of 1040 kg/ha[1].In India, Uttar Pradesh ranks second in terms of area (0.69 M ha), fourth in terms of production (0.89 Mt), and productivity 1290 kg/ha [2]. The major reasons for the low production of mustard are resource-poor farmers who are unable to implement scientific methods regarding agricultural management practices, especially nutrient management. The Indian mustard has a high demand for nutrients, and a lack of nutrients often results in poor output and nutrient use efficiency. Applying inorganic fertilizers continuously and exclusively causes soil sickness and disrupts the soil ecosystem, negatively impacting output and sustainability.Therefore, there is a need to find out some appropriate solution to fulfill the nutrient requirement of mustard crop.In this context, nanotechnology (Nano/Bio nano fertilisers), bio-stimulants, NPK consortia, and NPK (18:18:18) show promise and have the potential to greatly improve agricultural output and soil health. Nanofertilizers are defined as materials in the nanometer scale, usually in the form of nanoparticles, containing macro and micronutrients that are delivered to crops in a controlled mode [3]. The selective types of bacteria that fix nitrogen, PSB, as well as potash mobilizing bacteria found in NPK Consortia, serve to increase the supply of NPK to crops. In addition to trace elements like Zn, Mn, Mg, and Fe, seaweed provide nitrogen, phosphate, and potash. Keeping this in view, the present study wascarried out to study the foliar application of nano and non-nano fertilizers and their impact on growth and nutrient use efficiency of Indian mustard.

2. MATERIALS AND METHODS

An experiment was conducted during *rabi* 2020-2021 at the crop research center of SVPUA&T, Meerut, Uttar Pradesh. The investigation was carried out on well drained sandy clay loam soil, low in organic carbon (0.40 %) and available nitrogen (215 kg/ha), medium in available phosphorus (18.5 kg/ha), potassium (207 kg/ha), sulphur (14.5 kg/ha) and zinc (0.70 ppm) and moderately alkaline in pH (7.7) in randomized block designwith 12 treatments of nutrient management practices. A pre-sowing irrigation was applied before the trial began in the *rabi* season of 2020–21 to make sure there would be enough moisture when the seeds were sown. Following this, the area is ploughed twice—once with a moldboard plough and once with a cultivator—and then planked. After that, the plots were marked according to the layout plan and dressed properly with spade. NPK consortium is used as a seed treatment, at a rate of 50 ml in 600 ml of water for 6 kg of seed.Treated seed of the mustard variety 'Pusa Vijay' was sown in lines opened at a distance of 45 cm with the help furrow opener to facilitate 2-3 cm deep placement of seed. The entire amount of phosphorus, potassium, sulphur, and zinc, along with 50% of the nitrogen, were given at the time of sowing, and the remaining 50% was top-dressed in two equal portions after the first and second irrigations. Nano nitrogen (4 ml/litre), nano zinc (10 ml/liter), NPK 18:18:18 (5 g/litre) and bio-stimulants (625 ml/ha) were sprayed at 40 DAS by mixing in 500 liters of water/ha. Thinning of the crop was done 18 days after sowing in order to keep only one robust and healthy plant at a distance of 15 cm to maintain proper plant population. The three plants were selected from each plot for recording plant height (cm) and dry matter accumulation (g/plant) and finally averaged to assess the effect of treatments. The nutrient use efficiency was recorded during the year of experiment and expressed in standard units. Experimental data were statistically analyzed by using the analysis of variance (ANOVA) as described by [4].

3. RESULTS AND DISCUSSION

3.1 Plant height (cm): The data on plant height (cm) at various crop growth stages have been presented in Table & Fig 1. Application of nutrients, irrespective of sources and doses resulted in significant increase in plant height at all the growth stages. Further perusal of data revealed that reduction in NPK & S by 25%, reduced plant height significantly at 30 DAS except for treatment 75% NPK & S + Zn+ Bio-stimulants spray + Nano N + Nano Zn spray. The effect of nano fertilizers, bio-stimulants and NPK (18:18:18) was not perceptible at this stage as they were not applied by that time (30 DAS).The maximum height was recorded with 100% NPK & S + Zn,which was on at par with N-P-K & S (120-40-40 & 20 kg/ha), 100% NPK & S + bio-stimulants spray, 100% NPK & S + nano Zn spray and treatment75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray whereas the lowest plant height was observed at 30 DAS in control. Crop fertilized with 100% NPK & S + nano Zn spray registered maximum plant height at harvest which was on at par with the treatment 100% NPK & S + Zn, 100% NPK & S + bio-stimulants spray and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray with a plant height of 216.9, 210.4, 205.3 and 200.3 cm respectively.Similar results have been reported by **[5]** and **[6]** with the application of NPK + nano-Zn spray, recorded increase in plant height. Similar findings were also made by **[7]** they found that using nano-fertilizer in addition to conventional fertilizers increased plant height because nano-fertilizer can either provide nutrients for the plant or facilitate the transport or absorption of available nutrients, leading to maximum plant height.

3.2 Dry matter (g/plant): Significant variation was observed in the accumulation of dry matter (g/plant) under different nutrient management practices at all growth stages have been presented in Table & fig. 1. Dry matter accumulation at 30 DAS was found significantly higher with treatment 100% NPK & S + Zn, which was on at par with 100% NPK & S + nano Zn spray and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray. At later stages (60, 90 days and at harvest), application of either nano nutrient, bio-stimulants, NPK 18:18:18, or their simultaneous use with 100 % or 75 % NPK increased plant dry matter

S. No	Treatments	Plant height (cm)				Dry matter accumulation (g/plant)			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	Control	13.2	118.7	140.5	159.2	5.3	14.1	38.4	53.2
T_2	N-P-K & S (120-40-40 & 20 kg/ha)	17.3	130.7	158.3	177.4	7.7	17.6	46.8	65.7
T_3	100% NPK & S + Zn	19.0	150.7	186.5	210.4	8.8	26.3	61.4	94.6
T_4	100% NPK & S + Bio-stimulants spray	17.7	147.1	180.4	205.3	7.8	25.1	59.6	93.4
T_5	100% NPK & S + Nano Zn spray	18.1	155.6	191.7	216.9	8.0	30.2	64.8	102.7
T_6	75% NPK & S + NPK Consortia	16.6	128.6	155.6	175.2	7.1	16.6	44.8	64.2
T_7	75% NPK & S + Nano N spray	15.5	135.7	165.5	187.6	5.9	20.6	51.6	73.5
T_8	75% NPK & S + Nano N spray + Nano Zn spray	15.8	137.6	168.2	191.7	6.3	22.4	53.2	78.6
T_9	75% NPK & S + NPK Consortia + Nano Zn spray	17.0	142.9	172.4	195.7	7.4	24.2	56.8	88.5
T_{10}	75% NPKS + NPK (18:18:18) 0.5% spray	15.1	133.4	163.6	182.3	5.8	18.8	48.3	68.5
T_{11}	75% NPKS + NPK (18:18:18) 0.5% spray + Bio-stimulants spray	16.0	140.4	170.8	193.4	6.7	23.3	55.2	83.8
T_{12}	75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray	18.5	145.2	175.3	200.3	8.5	24.6	57.2	91.4
SEm±		***0.6***	***5.0***	***6.1***	***6.9***	***0.3***	***1.9***	***2.7***	***3.9***
CD(P = 0.05)		***1.8***	***10.8***	***17.3***	***17.3***	***0.8***	***5.7***	***7.7***	***11.6***

Table 1. Effect of doses and sources of nutrients on plant height (cm) and dry matter accumulation (g/plant) at various crop growth stages.

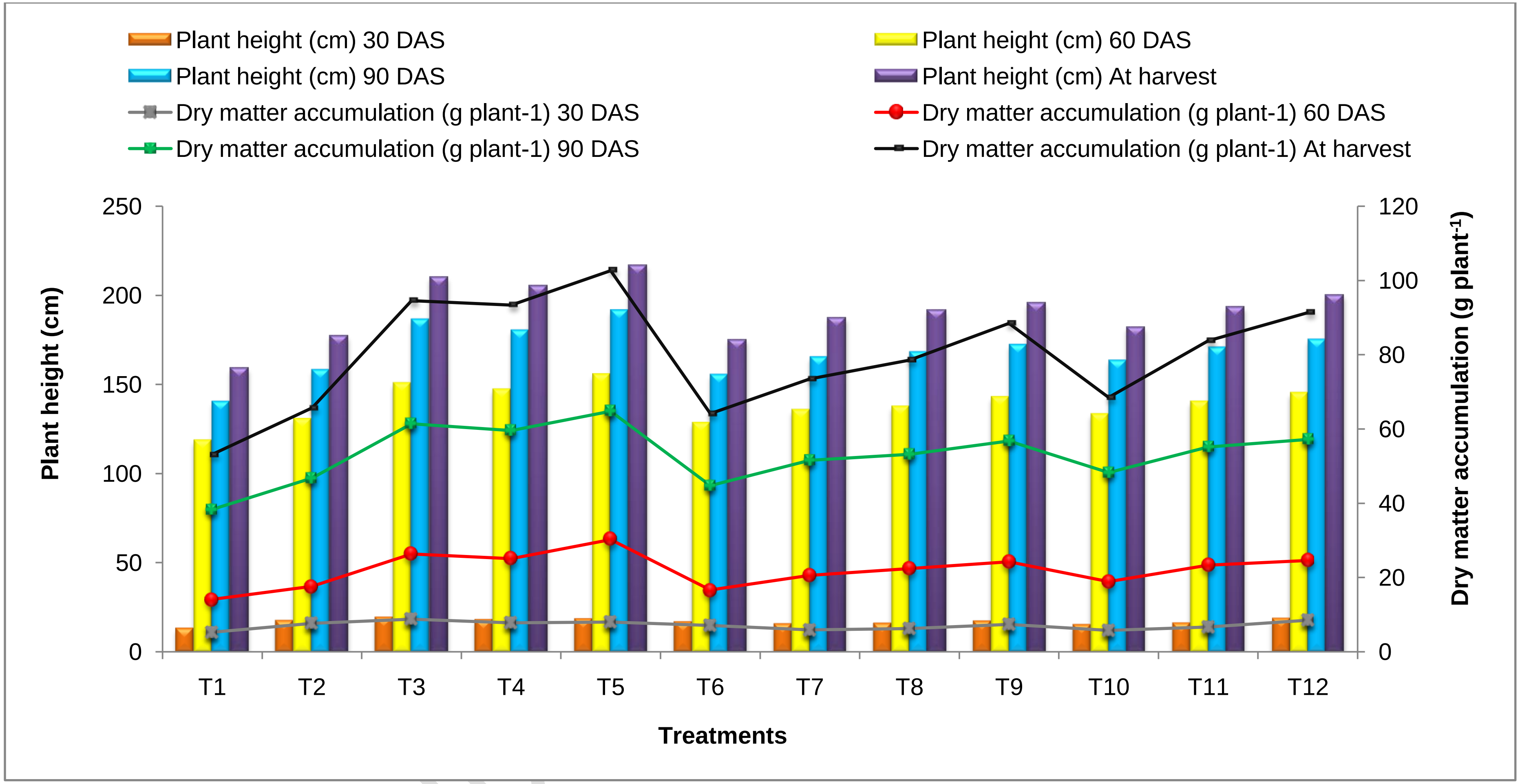

Fig. 1. Effect of doses and sources of nutrients on plant height (cm) and dry matter accumulation (g plant^{-1}) at various crop growth stages.

significantly over 100% NPK&S. The treatment 100% NPK & S + nano Zn spray recorded in maximum accumulation of dry matter at all growth stages (except 30 DAS) as compared to 100 % and 75 % recommended NPK&S and control, while it was at par with 100% NPK & S + Zn, 100% NPK & S + bio-stimulants sprayand 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray. Dry matter accumulation is influenced by crop canopy size and effectiveness in absorbing and utilizing solar energy. These findings are supported by**[8].**

3.3 Agronomic Efficiency: Different nutrient management practices had a substantial impact on the agronomic efficiency of N, P, and K has been presented in Table & Fig. 2. The treatment 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray led to higher agronomic efficiency of 10.4 for N, 31.2 for P and 31.2 for K as against 4.6, 13.8 and 13.8 respectively with treatment N-P-K & S (120-40-40 & 20 kg/ha). The use of nano N & Zn, bio- stimulants and NPK (18:18:18) separately or in combination with 75% of NPK&S, increased agronomic efficiency in comparison to 100% NPK&S, which suggested a significant rise in agronomic efficiency.

3.4 Physiological use-Efficiency: Nutrient management practices had a significant effect on the physiological use efficiency of mustard given in Table & Fig. 2. The treatment 75% NPK & S + NPK consortia recorded maximum physiological use-efficiency of N, P, K with 21.5, 73.7, and 36.4 respectively while minimum N & P use efficiency 10.4 & 27.3 with treatment 100% NPK & S + Zn and K (9.6) under the treatment 100% NPK & S + bio-stimulants sprayand 100% NPK & S + nano Zn spray. The substitution of NPK doses by 25% coupled with nano-nutrient (N & Zn), NPK consortia, N: P: K (18:18:18), bio-stimulants increased physiological efficiency in comparison to treatment N-P-K & S (120-40-40 & 20 kg/ha).

3.5 Partial Factor Productivity: The data on partial factor productivity (PFP) is presented in Table & Fig. 2. The highest partial factor productivity was recorded with treatment 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray whereas; lowest PFP was recorded under treatment N-P-K & S (120-40-40 & 20 kg/ha).

Nutrient use efficiency (agronomic, partial factor productivity and physiological use efficiency) is reported in Table 2 and observed significant results with the use of nano nutrients, bio-stimulants, NPK 18:18:18 and NPK consortia. Nutrient use efficiency is dependent upon grain yield, uptake of nutrients and the amount of nutrients applied. Application of 75% NPK & S with nano nutrient (N & Zn), bio-stimulants and zinc increased nutrient use efficiency significantly in comparison to 100% NPK & S, control and other treatments. This might be due to the fact that nano-fertilizers have large surface area and small particle size than the pore size of the root and leaves of the plant which can increase absorption into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer and other nutrients. These findings supported by **[9] and [10].**

3.6 Number of primary branches plant^{-1}: The data pertaining to number of primary branches at various stages of crop growth have been presented in table 3. In general the number of primary branches increased with advancement of crop age. Highest number of primary branches was observed under 100% NPK & S + Nano Zn spray (T_5) treatment *i.e.* 5.5, 7.2 and 8.3 at 60, 90 DAS and at harvest respectively. The minimum values for primary branches were 3.4, 5.0 and 5.5 at 60, 90 DAS and at harvest respectively in case of control. Among different treatments at60 DAS number of primary branches was found maximum under 100% NPK & S + Nano Zn spray (5.5) which was at par with 100% NPK & S + Zn, 100% NPK & S + Bio-stimulants spray, 75% NPK & S + NPK Consortia + Nano Zn spray, 75% NPKS+ NPK (18:18:18) 0.5% spray + Bio-stimulants spray and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray but significantly higher over rest of the treatments.

S. No	Treatments	Agronomic use-efficiency			Physiological use-efficiency			Partial factor productivity		
		N	P	K	N	P	K	N	P	K
T_1	Control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_2	N-P-K & S (120-40-40 & 20 kg/ha)	4.6	13.8	13.8	11.1	29.3	15.6	15.5	46.4	46.4
T_3	100% NPK & S + Zn	9.1	27.4	27.4	10.4	27.3	10.0	20.0	60.0	60.0
T_4	100% NPK & S + Bio-stimulants spray	8.1	24.3	24.3	10.7	28.0	9.6	19.0	56.9	56.9
T_5	100% NPK & S + Nano Zn spray	9.9	29.6	29.6	10.8	28.6	9.6	20.7	62.2	62.2
T_6	75% NPK & S + NPK Consortia	4.7	14.1	14.1	21.5	73.7	36.4	19.2	57.5	57.5
T_7	75% NPK & S + Nano N spray	6.6	19.7	19.7	15.0	47.7	16.0	21.1	63.2	63.2
T_8	75% NPK & S + Nano N spray + Nano Zn spray	7.1	21.2	21.2	13.3	37.1	12.1	21.6	64.7	64.7
T_9	75% NPK & S + NPK Consortia + Nano Zn spray	9.4	28.3	28.3	16.1	30.0	9.9	23.9	71.7	71.7
T_{10}	75% NPKS + NPK (18:18:18) 0.5% spray	6.3	19.0	19.0	12.7	37.3	17.6	20.8	62.4	62.4
T_{11}	75% NPKS + NPK (18:18:18) 0.5% spray + Bio-stimulants spray	7.7	23.0	23.0	11.3	29.4	9.7	22.1	66.4	66.4
T_{12}	75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray	10.4	31.2	31.2	11.8	56.0	13.0	24.9	74.6	74.6
SEm±		***0.3***	***0.8***	***0.8***	***0.4***	***1.3***	***0.5***	***0.3***	***0.4***	***0.4***
CD(P = 0.05)		***0.8***	***2.5***	***2.5***	***1.3***	***4.0***	***1.5***	***0.8***	***1.1***	***1.1***

Table 2. Effect of doses and sources of nutrients on nutrient use efficiency of nitrogen, phosphorus and potassium.

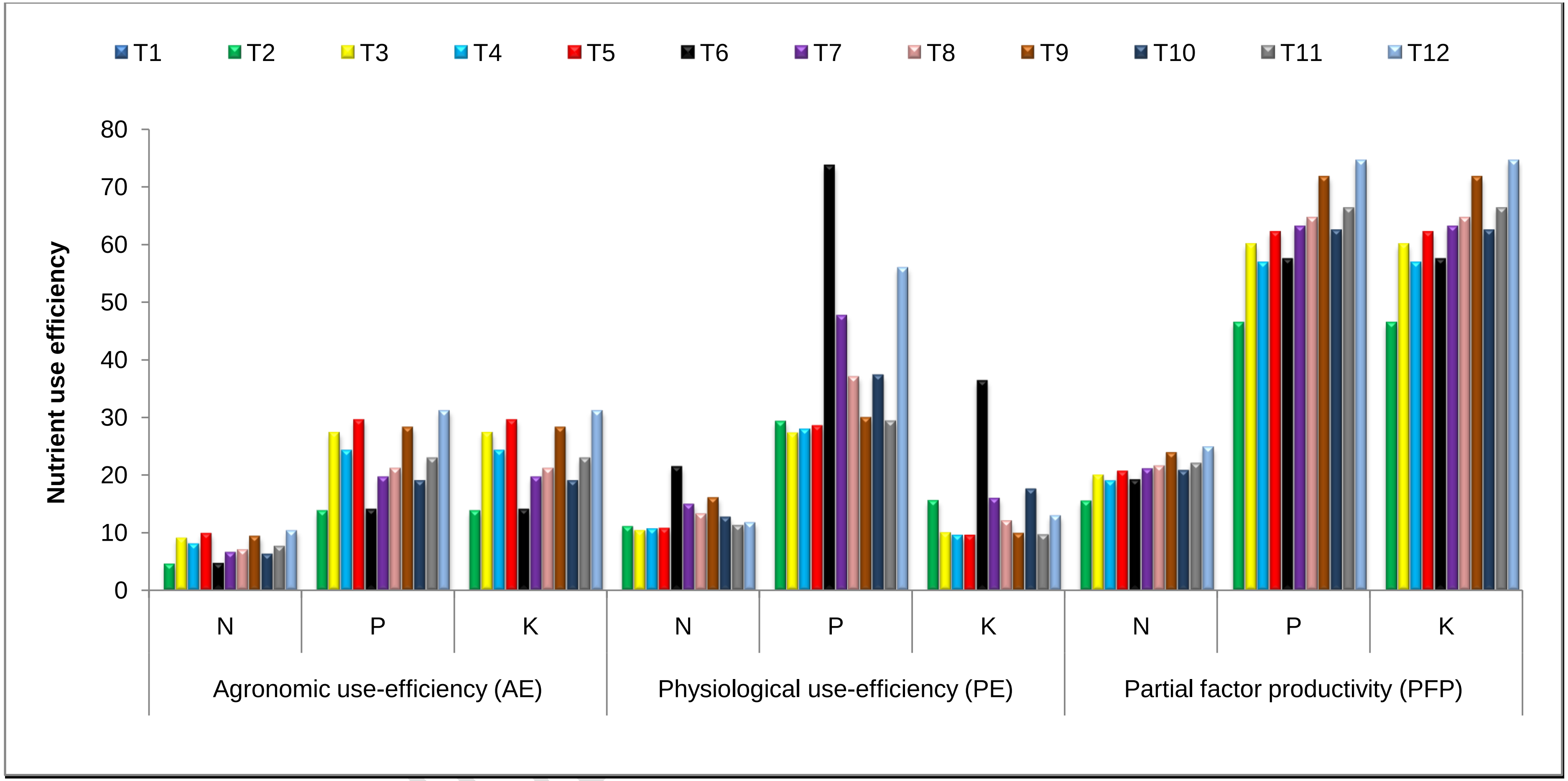

Fig. 2. Effect of doses and sources of nutrients on nutrient use efficiency of nitrogen, phosphorus and potassium.

However, at 60 DAS lowest number of primary branches was found in control (3.4). At 90 DAS same treatment as in 60 DAS 100% NPK& S + Nano Zn spray showed maximum value of primary branches (7.2) and it was on at par with 100% NPK & S + Zn, 100% NPK & S + Bio-stimulants spray, 75% NPK & S + NPK Consortia + Nano Zn spray, 75% NPKS + NPK (18:18:18) 0.5% spray + Bio-stimulants spray and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray. At harvest stage, primary branches did not differed significantly under various nutrient management practices. Primary branches recorded at harvest, varied from 5.5 under control to 8.3 under treatments 100% NPK & S + Nano Zn spray. Such differences were however non-significant.

3.7 Number of secondary branches plant^{-1}

The data pertaining to number of secondary branches at various stages of crop growth have been presented in Table 3. Data on secondary branches per plant was collected at 60 DAS, 90 DAS and at harvesting and it was reported that number of secondary branches at different crop growth stages were found significantly influenced with various treatments. At 60 DAS maximum number of secondary branches (8.3) were reported in the treatment having application 100% NPK & S + Nano Zn spray and which was on at par with treatment having 100% NPK & S + Zn (8.1), 100% NPK & S + Bio-stimulants spray (8.0), 75% NPK & S + NPK Consortia + Nano Zn spray (7.7) and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray (7.9).At 90DAS the number secondary branches was higher with 100% NPK & S + Nano Zn spray which was at par with 100% NPK & S + Zn, 100% NPK & S + Bio-stimulants spray and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray. Increase in the number of secondary branches is the result of all the metabolic reactions, varying nutrients levels, crop response to applied nutrients and increased photosynthetic activity due to 100% NPK application along with sulphur Nano Zn and bio stimulants which accelerated process of cell differentiation and activity of meristematic tissues also having more number of primary branches led to development of higher number of secondary branches.

3.8 Number of tertiary branches plant^{-1}

The data pertaining to number of tertiary branches at various stages of crop growth have been presented in Table 3. In general, the number of tertiary branches increased with advancement of crop age. Higher number of tertiary branches was recorded at 60 DAS with the application of 100% NPK & S + Nano Zn spray (3.2) which was statically at par with 100% NPK & S + Zn (3.1), 100% NPK & S + Bio-stimulants spray (3.1), 75% NPK & S + Nano N spray + Nano Zn spray (2.9), 75% NPK & S + NPK Consortia + Nano Zn spray (3.0), 75% NPKS + NPK (18:18:18) 0.5% spray + Bio-stimulants spray (3.0) and 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray (3.1). However, the lowest number of tertiary branches was recorded in control (2.0). At 90 DAS different treatment revealed significant effect of number of tertiary branches. Higher number of tertiary branches was recorded with the application of 100% NPK & S + Nano Zn spray (4.0) treatment, which was at par with 100% NPK & S + Zn (3.9), 100% NPK & S + Bio-stimulants spray (3.8), and 75% NPK & S + Zn+ Bio-stimulants spray + Nano N + Nano Zn spray (3.6). Similar trend was also reported at harvest.

Crop receiving 75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray proved significantly better than 100% NPK & S but remained at par with all other treatments nano nutrients with100% NPK& S. The profuse branching was due to the fact that nano fertilizer increased number of siliquae, more efficient nutrient utilization satisfying nutrient requirement of the crop and increased activity of chloroplast [11].

S. No	Treatments	Primary branches			Secondarybranches			Tertiary branches		
		60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T_1	Control	3.4	5.0	5.5	6.0	10.1	13.2	2.0	2.2	2.5
T_2	N-P-K & S (120-40-40 & 20 kg/ha)	4.1	5.8	6.2	6.7	11.0	14.7	2.4	2.7	3.2
T_3	100% NPK & S + Zn	5.4	7.0	7.9	8.1	13.2	18.0	3.1	3.9	4.5
T_4	100% NPK & S + Bio-stimulants spray	5.2	6.8	7.7	8.0	12.8	17.7	3.1	3.8	4.4
T_5	100% NPK & S + Nano Zn spray	5.5	7.2	8.3	8.3	13.4	18.5	3.2	4.0	4.7
T_6	75% NPK & S + NPK Consortia	3.9	5.6	6.0	6.5	10.9	14.2	2.2	2.5	2.8
T_7	75% NPK & S + Nano N spray	4.5	6.3	6.8	7.0	11.8	15.3	2.7	3.0	3.5
T_8	75% NPK & S + Nano N spray + Nano Zn spray	4.6	6.4	7.0	7.2	12.0	15.8	2.9	3.2	3.7
T_9	75% NPK & S + NPK Consortia + Nano Zn spray	5.0	6.6	7.3	7.7	12.5	17.0	3.0	3.4	4.0
T_{10}	75% NPKS + NPK (18:18:18) 0.5% spray	4.3	6.1	6.5	6.8	11.4	16.5	2.6	2.9	3.4
T_{11}	75% NPKS + NPK (18:18:18) 0.5% spray + Bio-stimulants spray	4.7	6.5	7.1	7.5	12.3	16.8	3.0	3.3	3.8
T_{12}	75% NPK & S + Zn + Bio-stimulants spray + Nano N + Nano Zn spray	5.0	6.7	7.5	7.9	12.7	17.3	3.1	3.6	4.2
SEm±		**0.3**	**0.2**	**0.9**	**0.3**	**0.4**	**0.6**	**0.1**	**0.1**	**0.2**
CD (P = 0.05)		**0.6**	**0.7**	**NS**	**0.6**	**0.7**	**1.2**	**0.3**	**0.4**	**0.6**

Table 3. Effect of doses and sources of nutrients on primary, secondary and tertiary branches.

4. CONCLUSION

Application of recommended dose of fertilizer (120-40-40-20 kg/ha NPKS) along with the foliar application of nano zinc (10 ml/liter), bio-stimulants (625 ml/ha) at 40 DAS in 500 liters of water and zinc (5 kg/ha at basal application) either simultaneously or separately resulted in higher crop growth and nutrient use efficiency of the mustard crop. This combination may further be recommended for better nutrient management practices in mustard crops.

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