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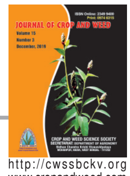

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Effect of nitrogen and zinc in nano forms on growth and productivity of potato (*Solanum tuberosum* L.) in inceptisols

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ABSTRACT

Nano-fertilizers have the potential to enhance crop productivity by increasing nutrient use efficiency. A field experiment was conducted during rabi seasons of 2019-20 and 2020-21 to determine the effect of nitrogen and zinc, when applied in nano form fertilizers on the growth and productivity of potato in inceptisols. The experimental design was randomized block with three replications comprising nine treatments viz. T_1- Control, T_2 - 100% Recommended Dose of Fertilizers (RDF) of NPK in conventional forms, T_3- Foliar application of Nano Nitrogen, T_4- Foliar application of Nano Zinc, T_5- Foliar application of Nano Nitrogen + Nano Zinc, T_6 -100% RDF of NPK + Foliar application of Nano Nitrogen, T_7 - 100% RDF of NPK + Foliar application of Nano Zinc, T_8 - 100% RDF of NPK + Foliar application of Nano Nitrogen + Nano Zinc, T_9 - 50% Recommended Dose of Nitrogen + 100% Recommended Dose of P & K + Foliar application of Nano Nitrogen + Nano Zinc. The results showed application of nano fertilizers significantly improved the leaf area index, plant height and dry matter production of potato. Regarding tuber yield of potato, the highest total tuber yield (34.15 tha^{-1}) was recorded in the treatment T_8. It was observed that the foliar application of only nano-N, only nano-Zn and only nano-N + nano-Zn increased the total yield of tubers by 83.13%, 45.87% and 149.27% respectively over the control. It was also observed that foliar application of nano-N + 100% RDF of NPK, nano-Zn + 100% RDF of NPK and nano-N + nano-Zn with 100% RDF of NPK increased the total tuber yield of potato by 29.73%, 14.75% and 36.11% respectively over the application of only 100% RDF of NPK. Result showed that foliar application of nano-N + nano-Zn with 100% RDF of NPK enhanced the uptake of N, P, K & Zn by 36.02%, 36.01%, 36.02% and 66.16% respectively over 100% RDF of NPK application. The economic analysis depicted the maximum net return (Rs. 1,71,466ha^{-1}) and BCR (2.69) from T_8 treatment i.e. application of 100% RDF of NPK + Foliar application of Nano Nitrogen + Nano Zinc,.

Keywords : fertilizer management, foliar application, nano nitrogen, nano zinc, potato, productivity

More innovative nutrient management approach which can enhance the agricultural system productivity in an environment friendly manner is the need of the hour. Nano-fertilizers have the potential to enhance crop productivity by increasingnutrient use efficiency. Tarafdar *et al.* (2014) reported that nanoparticles can enter through shoots and roots of the plants. Normally more penetration was found through stomata and cuticle. After entering, the nanoparticle moves through the cell sap. While transport they trigger various enzyme systems and most of the particles may agglomerate to form mega particles on the pathway and mostly gets deposited at the vacuole.Effect of NFs like nitrogen-NF & Zinc-NF on potato crop were also experimented in this regard. Zareabyaneh and Bayatvarkeshi (2015) reported that nano-N increased the yield of potato crop. The application of zinc nano fertilizers (ZnO) enhanced plant height, leaf area, dry matter production, protein content and yield of potato as reported by Seleiman *et al.* (2020). Potato is a heavy nutrient feeder crop because of their bulk yield within a short period of time bearing shallow root system. Zinc is most deficient micronutrient in Indian soils (52%) (Anonymous, 2009). Hence, application of micronutrients becomes essential to increase the productivity of potato.Use of synthetic fertilizers under intensive agriculture was reported to record lower NUE values (Guo *et al*., 2018). Intensive use of synthetic fertilizers in bulk amount may pollute our environment by increasing soil degradation, eutrophication,air pollution and groundwater contamination (Seleiman *et al*., 2020; Eid *et al*., 2020; Czymmek *et al*., 2020). Further, over-application of synthetic fertilizers results into enhanced cost of production and reduced proût for farmers (Diatta*et al*., 2020; Seleiman*et al*., 2020).Nano fertilizers when applied foliar are readily absorbed by plants because their size is less than stomatal openings in leaves and thereby reduce fertilizer consumption by increasing NUE and reduce environmental pollution if applied with proper precautions. Significant increment in yield was reported by foliar application of 640 mg ha^{-1} (40 ppm concentration) of nano-phosphorus in pearl millet and

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cluster bean under arid environment (Tarafdar *et al.,* 2012a; Tarafdar *et al.,* 2012b). Raliya (2015) suggested that TiO_2nano particles used as plant fertilizer for mung bean to enhance crop production. Prasad *et al.* (2012) recorded 30.5% higher pod yield with the application of nanoscale ZnO at 2g 15 L^{-1} + NPK with respect to only NPK application.Considering the above aspects,the present investigation was started to study the impact of nano nitrogen and nano zinc on growth parameters and yield of potato crop in inceptisols.

MATERIALS AND METHODS

The field experiment was conducted during rabi seasons of 2019-20 and 2020-21 to determine the effect of nano nitrogen and nano zinc on growth and productivity of potato at university research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal.The experimental design utilized was randomized block with three replications comprising nine treatments viz. T_1- Control (without fertilizer), T_2 - 100% Recommended Dose of Fertilizers (RDF) of NPK in conventional forms, T_3- Foliar application of Nano Nitrogen, T_4- Foliar application of Nano Zinc, T_5- Foliar application of Nano Nitrogen + Nano Zinc, T_6 -100% RDF of NPK + Foliar application of Nano Nitrogen, T_7 - 100% RDF of NPK + Foliar application of Nano Zinc, T_8 - 100% RDF of NPK + Foliar application of Nano Nitrogen + Nano Zinc, T_9 - 50% Recommended Dose of Nitrogen + 100% Recommended Dose of P & K + Foliar application of Nano Nitrogen + Nano Zinc.The soil texture of the experimental field was sandy loam and pH (7.45) was neutral in reaction. The initial soil recorded 0.53% of organic carbon, 185.3kg of available N ha^{-1}, 15.75kg of available P_2O_5 ha^{-1}, 131.05kg of available K_2O $ha^{-1}$and 1.42 mg of available Zn kg^{-1}soil. Potato variety used was Kufri Himalini.Seed tubers (30–40 g each) were planted at a spacing of 60 cm X 20 cm during the end of November.The plot size was 3m X 4m. The recommended dose of fertilizer was 200, 150, 150 kg N, P_2O_5, K_2O ha^{-1}. The source of nitrogen, phosphorus and potassium were urea, single super phosphate (SSP) and muriate of potash (MoP) respectively. 50% recommended dose of nitrogen and 100%recommended dose of phosphorus and potassium were applied treatment wise during the final land preparation. Earthing up was done at 30 days after application of remaining 50% nitrogen.The nano nitrogen (in nano urea form) and nano zinc (biologically synthesized nano zinc oxide coated with mother protein)used were marketed by IFFCO, India. Two sprays of nano nitrogen @ 4ml L^{-1} and nano zinc @ 4ml L^{-1} were applied at 25 days after planting (DAP) and 45 DAP. Plant protection measures were followed as per schedule. Regular monitoring was done. The crop was harvested 10 days after dehaulming.From each net plot area tuber yield was recorded. The economic analyses were done by taking into consideration of prevailing market prices.Statistical analyses were done by using MSTAT-C software.

RESULTS AND DISCUSSION

Effect on plant emergence, plant height and number of shoots per plant

The result showed that there was no significant effect of nano fertilizer treatments on plant emergence,plant emergence varied from 98.50% to 99.60%. It was noted that the plant height varied significantly from 39.8 cm in control plot (T_1)to 63.4 cm in plots of T_8 (Table 1). Highest plant height (63.4 cm) was observed in the treatment T_8 in which 100% RDF of NPK+ Foliar spray of nano-N + foliar spray of nano-Zn applied at 25 & 45 DAP and it was statistically at par with treatment T_9 *i.e.* application of 50% RD_N + 100% RD_{PK} + nano-N and nano-Zn as foliar application and T_6 i.e.100% Recommended Dose of NPK + foliar nano-N-sprays at 25 and 45 DAP. Application of nano-N and nano-Zn significantly improved the plant height of potato which might be due to the effect of nano-N that enhanced the formation of chlorophyll, the rate of photosynthesis, dry matter production, consequently, the overall plant growth. Similar findings were also reported byAl-juthery (2018), Raliya *et al.* (2016), Al-juthery and Al-Maamouri (2019) and Shami *et al.* (2019).The least plant height (39.8cm) was recorded with treatment T_1i.e. the control plot. It was revealed from the experiment that the number of shoots per plant of potato was significantly influenced by the foliar sprays of nano nitrogen and nano zinc (Table 1).The number of shoots per plant varied from 3.02 to 4.80. The highest average number of shoots per plant (4.80) was recorded in the treatment T_8i.e. the application of 100% RDF of NPK + foliar nano nitrogen + nano zinc sprays which was found statistically higher than all other treatments that might be due to the effect of combined application of nano-N and nano-Zn that enhanced the activity of indole acetic acid (IAA).

Effect on leaf area index and dry matter production

Leaf area index of potato showed increasing trend up to 65 DAP then it started declining with maturity of the crop (Table 2).Results revealed that Leaf Area Index (LAI) of potato was significantly influenced by the treatments. LAI value varied from 1.68 to 2.12 at 50 DAP, 1.71 to 2.92at 65 DAP and 1.38 to 2.75at 80 DAP.The highest LAI value was recorded with treatment T_8 (100% RDF of NPK+ foliar nano-N + nano-Zn application)at all dates of observation.In control plot, the lowest LAI was recorded at all dates of observation

Table 1: Plant emergence, no. of shoots per plant and plant height of potato as influenced by nano-nitrogen and nano-zinc application (pooled data of two years)

Treatments		Emergence (%)	No. of shoots plant^{-1}	Plant height (cm)
T_1	Control	98.8	3.02	39.8
T_2	100% RDF of NPK	99.4	4.05	56.6
T_3	Foliar nano-N	98.5	3.61	52.2
T_4	Foliar nano-Zn	99.2	3.45	51.6
T_5	Foliar nano-N + nano-Zn	99.6	3.70	57.2
T_6	T_2 + Foliar nano-N	99.4	4.38	59.4
T_7	T_2 + Foliar nano-Zn	99.5	4.20	57.2
T_8	T_2 + Foliar nano-N + nano-Zn	99.6	4.80	63.4
T_9	50% RD_N +100% RD_{PK}+ Foliar nano-N + nano-Zn	98.9	3.85	60.2
	SEm(±)	**0.02**	**0.14**	**1.50**
	LSD (0.05)	**NS**	**0.42**	**4.50**

Table 2: Leaf Area Index (LAI) of potato as influenced by nano-nitrogen and nano-zinc application (pooled data of two years)

Treatments		LAI at different DAP		
		50 DAP	**65 DAP**	**80 DAP**
T_1	Control	1.68	1.71	1.38
T_2	100% RDF of NPK	2.08	2.71	2.53
T_3	Foliar nano-N	2.06	2.36	2.15
T_4	Foliar nano-Zn	2.03	2.25	2.03
T_5	Foliar nano-N + nano-Zn	2.07	2.46	2.33
T_6	T_2 + Foliar nano-N	2.10	2.80	2.68
T_7	T_2 + Foliar nano-Zn	2.09	2.75	2.55
T_8	T_2 + Foliar nano-N + nano-Zn	2.12	2.92	2.75
T_9	50% RD_N +100% RD_{PK}+ Foliar nano-N + nano-Zn	2.08	2.63	2.45
	SEm(±)	**0.03**	**0.03**	**0.05**
	LSD (0.05)	**0.10**	**0.11**	**0.15**

Table 3: Total dry matter production (DM) of potato as influenced by nano-nitrogen and nano-zinc application (pooled data of two years)

Treatments		Dry Matter (gm^{-2}) at different DAP		
		50 DAP	**65 DAP**	**80 DAP**
T_1	Control	174.88	242.30	285.50
T_2	100% RDF of NPK	425.25	657.50	760.50
T_3	Foliar nano-N	280.30	429.42	502.85
T_4	Foliar nano-Zn	250.48	368.95	415.25
T_5	Foliar nano-N + nano-Zn	368.36	565.50	665.80
T_6	T_2 + Foliar nano-N	500.42	749.65	936.20
T_7	T_2 + Foliar nano-Zn	455.75	670.50	832.62
T_8	T_2 + Foliar nano-N + nano-Zn	525.50	789.35	988.76
T_9	50% RD_N +100% RD_{PK}+ Foliar nano-N + nano-Zn	374.20	574.23	701.56
	SEm(±)	5.70	10.25	12.30
	LSD (0.05)	17.21	30.80	36.90

Table 4: Grade-wise and total tuber yield of potato as influenced by nano-nitrogen and nano-zinc application (pooled data of two years)

Treatment		Grade-wise tuber yield (tha^{-1})					Yield on dry weight basis (tha^{-1})	
		0-25g	25-50g	50-75g	>75g	Total	Tuber	Haulm
T_1	Control	1.26	2.44	2.74	1.80	8.24	1.38	1.20
T_2	100% RDF of NPK	1.33	5.14	6.81	11.81	25.09	4.22	3.12
T_3	Foliar nano-N	1.98	3.38	4.29	5.44	15.09	2.54	2.45
T_4	Foliar nano-Zn	1.97	2.07	4.73	3.25	12.02	2.02	2.00
T_5	Foliar nano-N + nano-Zn	2.03	4.81	5.62	8.08	20.54	3.45	2.98
T_6	T_2 + Foliar nano-N	1.63	6.66	9.74	14.52	32.55	5.47	3.69
T_7	T_2 + Foliar nano-Zn	1.37	5.40	9.77	12.25	28.79	4.84	3.35
T_8	T_2 + Foliar nano-N + nano-Zn	1.66	5.14	9.96	17.39	34.15	5.74	3.89
T_9	50% RD_N +100% RD_{PK}+ Foliar nano-N + nano-Zn	1.37	5.33	5.73	10.07	22.50	3.78	3.10
	SEm(±)	0.09	0.18	0.37	0.75	0.81	0.23	0.15
	LSD (0.05)	NS	0.54	1.10	2.25	2.43	0.70	0.45

Table 5: Nutrient uptake by potato as influenced by nano-nitrogen and nano-zinc application (pooled data of two years)

Treatments		Nutrient Uptake			
		Total N uptake (Kg ha^{-1})	P uptake (Kg ha^{-1})	K uptake (Kgha^{-1})	Zn uptake (g ha^{-1})
T_1	Control	35.05	9.80	50.37	56.03
T_2	100% RDF of NPK	107.19	29.96	154.03	175.33
T_3	Foliar nano-N	64.52	18.03	92.71	103.12
T_4	Foliar nano-Zn	51.31	14.34	73.73	115.54
T_5	Foliar nano-N + nano-Zn	87.63	24.50	125.93	177.34
T_6	T_2 + Foliar nano-N	138.94	38.84	199.66	212.08
T_7	T_2 + Foliar nano-Zn	122.94	34.36	176.66	258.85
T_8	T_2 + Foliar nano-N + nano-Zn	145.80	40.75	209.51	291.33
T_9	50% RD_N +100% RD_{PK}+ Foliar nano-N + nano-Zn	96.01	26.84	137.97	201.22
	SEm(±)	3.4	1.4	5.9	19.9
	LSD (0.05)	10.2	4.2	17.8	59.8

Table 6: Economics and net returns of potato cultivation as influenced by nano-nitrogen and nano-zinc application

Treatments	Yield (tha^{-1})	Cultivation cost (Rs. ha^{-1})			Total cost (Rs. ha^{-1})		Sale price (Rs.t^{-1})	Net returns (Rs.ha^{-1})	B.C. Ratio
		Seed	Fertilizer	Cultivation	Inputs	Produce			
T_1	8.24	32000	0	50000	82000	65920	8000	-16080	0.80
T_2	25.09	32000	14614	50000	96614	200720	8000	104106	2.08
T_3	15.09	32000	1920	50600	84520	120720	8000	36200	1.43
T_4	12.02	32000	2000	50600	84600	96160	8000	11560	1.14
T_5	20.54	32000	3920	50600	86520	164320	8000	77800	1.90
T_6	32.55	32000	16534	51200	99734	260400	8000	160666	2.61
T_7	28.79	32000	16614	51200	99814	230320	8000	130506	2.31
T_8	34.15	32000	18534	51200	101734	273200	8000	171466	2.69
T_9	22.5	32000	12414	51200	95614	180000	8000	84386	1.88

as no fertilizer application was practiced there. Similar findings were also reported by Seleiman *et. al.* (2020); Moghaddasi *et. al.* (2017); Tarafdar *et. al.* (2014); Monreal *et. al.* (2016). Application of nano-N and nano-Zn had a significant effect on dry matter production. Plants showed an increasing trend of dry matter production up to harvesting in all treatments (Table 3). Dry matter production varied from 174.88 to 525.50 gm^{-2} at 50 DAP, 242.30 to 789.35 gm^{-2} at 65 DAP and 285.50 to 988.76 gm^{-2} at 80 DAP. Treatment T_8 (100% RDF of NPK+ foliar nano-N + nano-Zn application) recorded highest dry matter production at all dates of observations.The lowest dry matter production was recorded under control (T_1). The higher plant height and large number of leaves per plants favoured higher canopy development under different nutrient management. Enhanced chlorophyll concentration might have increased the light interception, absorption and utilization of solar radiation thus enhanced photosynthesis which was reflected in LAI and dry matter production. It also might be due to the higher uptake of nutrients, better source to sink relation and higher translocation of starch. This finding was in conformity with Lenka and Das (2019).

Grade wise tuber yield

Data showed that yield of potato tubers under different grades were significantly influenced by the application of nano-N and nano-Zn (Table 4). It was observed that application of nano-N and nano-Zn had no significant impact on yield of 0 to 25 g tubers. It was observed that the yield of 0 to 25 g tubers varied from 1.26 to 2.03 tha^{-1} due to application of different treatments. The highest yield (2.03 tha^{-1}) of 0 to 25 g tubers was observed in the treatment T_5(2 foliar sprays of nano-N + 2 foliar sprays of nano-Zn). The lowest yield of 0 to 25 g tubers (1.26 tha^{-1}) was recorded in the treatment T_1 (control).The highest yield (6.66 tha^{-1}) of 25-50 g tubers was observed in the treatment T_6(100% RDF of NPK+ 2 foliar sprays of nano-N) and lowest yield (2.07 tha^{-1}) was observed in the treatment T_4. Yield of 50 to 75 g tubers varied significantly from 2.74 to 9.96 tha^{-1}. The treatment T_8i.e.100% RDF of NPK+ foliar nano-N + nano-Zn application) recorded highest yield of 50 to 75 g grade tubers and it was at par with the treatment T_7 (100% RDF of NPK+ 2 foliar sprays of nano-Zn) and T_6 (100% RDF of NPK+ 2 foliar sprays of nano-N), whereas the control treatment recorded the lowest yield of 50 to 75 g tubers. In case of marketable grade tuber production (>75g) the treatment T_8(100% RDF of NPK+ foliar nano-N + nano-Zn application) recorded the highest yield (17.39 tha^{-1})which was followed by treatment T_6. The lowest yield (1.80 t ha^{-1}) under this grade was recorded with treatment T_1 (Control).

Total tuber yield

Total tuber yield of potato was significantly influenced by the application of nano-N and nano-Zn (Table 4). It was recorded that the total tuber yield varied significantly from 8.24 to 34.15 tha^{-1}. The highest total tuber yield (34.15 tha^{-1}) was recorded with the treatment T_8i.e.100% RDF of NPK+ foliar nano-N + foliar nano-Zn application and it was at par with the treatment T_6i.e. 100% RDF of NPK+ 2 foliar sprays of nano-N which might be due to the fact that nano-N and nano-Zn increased the average weight of individual tubers, more marketable grade tuber production, thereby increased the total tuber yield due to increased translocation of starch from source to sink. Similar observations were reported by Sharma *et al.* (1988), Uppal and Singh (1989), Das and Chakraborty (2018) and Lenka and Das (2019).Whereas in control treatment (T_1)the total tuber yield (8.24 t/ha) reduced drastically as potato is a heavy feeder crop. It was revealed that the foliar application of only nano-N, only nano-Zn and only nano-N + nano-Zn increased the total yield of tubers by 83.13%, 45.87% and 149.27% respectively over the control (T_1). It was also observed that foliar application of only nano-N + 100% RDF of NPK, foliar application of only nano-Zn + 100% RDF of NPK and foliar application of nano-N + nano-Zn with 100% RDF of NPK increased the total tuber yield of potato by 29.73%, 14.75% and 36.11% respectively over the application of only 100% RDF of NPK. Thus, foliar application of nano-N + nano-Zn in combination was found more effective than their single application in increasing the total tuber yield of potato and foliar application of nano-N + nano-Zn with 100% RDF of NPK was found most effective than the application of 100% RDF of NPK with any single application of nano-N or nano-Zn by foliar means.

Dry weight yield of tubers and haulms

A significant variation (1.38 to 5.74 tha^{-1}) in dry weight yield of tubers were recorded due to application of different treatments (Table 4). The highest total dry weight yield of tubers (5.74 tha^{-1}) was recorded in the treatment T_8 (100% RDF of NPK+ foliar nano-N + foliar nano-Zn application) and it was at par with treatment T_6. Treatment T_1 (control) recorded the lowest total dry weight yield (1.38 tha^{-1}) of tubers. From the recorded result it was revealed that the foliar application of only nano-N, only nano-Zn and nano-N + nano-Zn increased the total dry weight yield of tubers by 84.06%, 46.38% and 150% respectively over the control (T_1). It was also revealed that foliar application of only nano-N + 100% RDF of NPK, only nano-Zn + 100% RDF of NPK and nano-N + nano-Zn + 100% RDF of NPK increased the total dry weight yield of tubers by 29.62%, 14.69% and

36.02% respectively over the application of 100% RDF of NPK. Whereas foliar application of nano-N + nano-Zn along with 50% RD_N + 100% RD_{PK}decreased the total dry weight yield of tubers over 100% RDF of NPK application. Dry weight yield of haulms varied significantly from 1.20 to 3.89 tha^{-1}. The highest total dry weight yield (3.89 tha^{-1}) of haulms was observed with $T_8$and it was at par with treatment T_6. The lowest total dry weight yield of haulms (1.20 tha^{-1}) was recorded in T_1 (control) treatment.

Nutrient uptake

The application of nano-nitrogen and nano-zinc had a significant effect on the uptake of nitrogen, phosphorus, potassium and zinc (Table5).The higher uptake of N, P, K and Zn were the resultant of higher yield. From the recorded data it was observed that the total N uptake varied significantly from 35.05 to 145.80 kg ha^{-1}, P uptake varied significantly from 9.80 to 40.75 kg ha^{-1}, K uptake varied significantly from 50.37 to 209.51 kg ha^{-1}and zinc uptake varied significantly from 56.03 to 291.33 g ha^{-1}due to the application of different treatments. The highest total nitrogen, phosphorus, potassium and zinc uptake were recorded with the treatment T_8 (100% RDF of NPK+ foliar nano-N sprays + foliar nano-Zn sprays) and it was at par with the treatment T_6(100% RDF of NPK+ 2 foliar sprays of nano-N). Similar observations were also reported by Manikandan and Subramanian (2016), Ha *et al.* (2018), Raliya *et al.* (2016). The lowest total nitrogen, phosphorus, potassium and zinc uptake were recorded with the treatment T_1 (control). Foliar application of only nano-N, only nano-Zn and only nano-N + nano-Zn increased the total nitrogen uptake of potato by 84.08%, 46.39% and 150.01%; phosphorus uptake by 83.98%, 46.33% and 150%; potassium uptake by 84.05%, 46.38% and 150% and zinc uptake by 84.04%, 106.21% and 216.5% respectively over the control (T_1). Increased zinc concentration and zinc uptake due to nano zinc application was also reported by Moghaddasi *et al.* (2017). Result showed that foliar application of nano-N + nano-Zn with 100% RDF of NPK enhanced the uptake of N, P, K & Zn by 36.02%, 36.01%, 36.02% and 66.16% respectively over 100% RDF of NPK application. Thus, foliar application of nano fertilizers along with 100% RDF of soil applied NPK was found more effective than their foliar application alone without any RDF of NPK in increasing the nutrient uptake of all other macro and micronutrients in potato.

Economics

It was revealed from the result, recorded from field experiment that net returns from potato cultivation ranged from Rs. -16,080 ha^{-1} to Rs. 1,71,466 ha^{-1} (Table 6). The highest net return (Rs. 1,71,466ha^{-1}) and benefit cost ratio (2.69) was observed under the treatment $T_8$with the application of 100% RDF of NPK+ foliar nano-N sprays + foliar nano-Zn sprays. The lowest net return (Rs. -16080ha^{-1}) and benefit cost ratio (0.80) was recorded under the treatment T_1 (control). It was evident that the application of 100% RDF of NPK+ 2 foliar spraying of nano-N + 2 foliar spraying of nano-Zn increased the net return by 64.7% over the application of hundred percent recommended dose of NPK.

It can be concluded from the present study that from yield and economic point of view, application of 100% recommended dose of NPK along with foliar application of both nano nitrogen and nano-zinc was the best treatment in increasing the growth and productivity of potato.Also it was found that for a heavy feeder crop like potato particularly with a heavy feeder cultivar like Kufri Himalini, application of nano nitrogen and nano zinc with this applied dose and frequency failed to curtail the dose of bulk chemical fertilizer particularly urea but it was found economically viable option to enhance productivity. Further study needed for dose and frequency standardization of nano nutrients for a crop like potato.

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