Effect of particle Size and Concentration of ZnO Nanoparticles on Growth, Yield and Seedling parameters in Buckwheat (*Fagopyrum esculentum* L.)

Abstract

The experiment was conducted in both field and lab conditions to study the Effect of Particle Size and Concentration of ZnO Nanoparticles on Growth, Yield and Seedling Parameters in Buckwheat (*Fagopyrum esculentum* L.) Under Late Sowing Conditions in Eastern Uttar Pradesh Region the lab experiment was performed in CRD with four different size ranges of zinc oxide Nanoparticles (20-30nm, 40-50nm, 60-80nm, 80-100nm) each of three concentrations (30PPM, 60PPM, 80PPM). The field experiment was performed during *Rabi* season of 2022-2023 in Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj Uttar Pradesh with a control was laid out in factorial RBD with 3 Replications. The results revealed that T1(20-30nm, 30PPM for 8hrs) shows greater Performance among parameters viz Plant height 30 DAS (23.45), Plant height 80 DAS (91.36), Days to first flowering (26.11), Number of Branches (4.43), Seeds per Plant (142.39), Seed yield per plot (11.87), Seed yield per hectare (1.19), Economic Yield (11.87), Biological Yield (32.76). and Harvest Index (36.23) and T3(20-30nm, 80PPM for 8hrs) exhibit greater in Leaf surface area (22.37), Test Weight (27.34). The lab results revealed the treatment T1(20-30nm, 30PPM for 8hrs) showing greater performance in Germination Percentage (95.63), Root Length (14.57), Seedling Length (24.76), Vigor Index-1 (2369.25), Electric conductivity (0.327), Protein content (13.59), Seed metabolic efficiency and T3 (20-30nm, 80PPM for 8hrs) shows greater Performance in Shoot length (11.57), Fresh Weight (2.19), Dry Weight (0.80), Vigor Index-2 (72.67), Seed Density (0.8), Chlorophyll Content (2.84), Dehydrogenize Activity (0.996).

Key words: Buckwheat, Zinc Oxide, Yield, Chlorophyll content, Protein content.

1. Introduction

Buckwheat (*Fagopyrum esculentum* L.), Chromosome Number 2n = 16 is a Cross pollinated annual crop that belongs to the family Polygonaceae. It is grown as a cover crop and for its seeds, which resemble grains. Buckwheat, despite its name, is not related to wheat and is not a grain at all. The names boc from beechnut and wheat from wheat were combined to form the term "buckwheat" **(Robinson, 1980).** Because the plant's fruit resembled that of the beechnut, the word "beech" was invented to describe it. Due to its function and chemical makeup resembling that of traditional cereals, it is a member of a dietary category known as pseudo cereals **(Campbell, 1997).** Buckwheat, a pseudo-cereal that grows in easy conditions, has the potential to become an important source of nutrition for the **"Starving World" (Leder *et al.*, 2009**). Buckwheat is quite sensitive to low temperatures, while it tolerates hot temperatures relatively well **(Germ and Gabreski 2016).** Buckwheat grows best at temperatures ranging from 18 to 23 degrees Celsius. During the spring and autumn cultivation seasons, the average temperature in Korea is 7.3 °C and 25 °C, respectively **(Jung *et al.* 2015).** Reduced temperatures affect fertilization processes, resulting in reduced grain output in the spring season **(Farooq *et al.* 2016).**

Germplasm was morphologically characterized based on stem color, seed coat color, and seed morphology. Green, light Green, Pale Red, Crimson, and Dark Red Stem colors were noted. White, Grey, Pale Brown, Dark Brown, and Black Seed Coat color were noted.Documented s\Seed shape for o\Oval, egg-shaped (ovate), Triangular-type, and winged-form seeds. The grains are rich in polyphonies e.g., rutin and catechins which are reported to have antioxidant activity **(Morishita et al., 2007**). Buckwheat flowers are perfect but incomplete. They have no petals, but the calyx has the appearance of petals. Flowers occur in compact racemes, either terminally on the main stem or on branches from the axil of leaves.

Zinc oxide Nanoparticles have lately been employed and investigated for their impact on plant development in Zn-Nano formulations. Seed, foliar, and soil treatments are used to apply ZnO Nanoparticles. Among these applications, seed invigoration procedures like as seed priming and coating with ZnO Nanoparticles are regarded as relatively inexpensive and ecologically safe. Seed treatments that comprise the addition of ZnO Nanoparticles at the required concentrations result in ZnO Nanoparticles absorption by the seed coat, followed by their penetration and migration through seed tissue layers, which enhances germination and crop biomass. As a result, seed priming and seed coating are a targeted delivery approach for increasing the availability of micronutrients and other elements during the early growth of plants. Cultivation practices, as well as revolutionary seed invigoration techniques and precision farming, can boost seed germination potential, seedling vigor, photosynthesis, and reproductive development, resulting in increased production. Recent Nano-priming, a revolutionary approach of seed priming using designed Nanoparticles, has earned recognition for its unique physiochemical properties in boosting crop output and protection.

Globally, it has been used as Nano-fertilizer especially in Zn-deficit areas in order to enhance plant growth and develop **(Sabir *et al.*, 2020).** The addition of Nanoparticles may ameliorate nutrient deficiency and improve crop production **(Dimkpa *et al.*, 2017).** Recent studies have shown a positive impact of ZnO Nanoparticles on plant growth and physiology due to their wide spread applications in agriculture sector.

Objectives :

1. To evaluate the Effect of ZnO Nanoparticles on Growth and Yield parameters of Buckwheat.
2. To find out the Effect of ZnO Nanoparticles on Seedling parameters and Chlorophyll Content, Protein Content and Dehydrogenize Activity of Buckwheat

2. Methods and materials

The experiment was conducted during the Rabi Season of 2022 at field experimentation centre of Department of Genetics and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. The experimentation site is situated 98m above sea level at 25.570N latitude and 81.560N longitude. Buckwheat variety "IC-107575" sown at 25 X 15 cms which were treated with treatments of different concentrations of ZnO nanoparticles of different sizes.. The 13 treatment combinations along with untreated control were employed in the present study. The details of the treatment combinations, their dosage and the duration of the treatment were, T_0- Control, T_1- ZnO @20-30 nm of 30 PPM, T_2- @20-30 nm of 60 PPM, T_3-@20-30 nm of 80 PPM, T_4- @40-50 nm of 30 PPM, T_5-@40-50 nm of 60 PPM, T_6-@40-50 nm of 80 PPM, T_7-@60-80 nm of 30 PPM, T_8-@60-80nm of 60 PPM, T_9-@60-80 nm of 80 PPM, T_{10}-@80-100 nm of 30 PPM, T_{11}-@80-100 nm of 60 PPM, T_{12}-@80-100 nm of 80 PPM For 8 hours.

2.2 Methodology:

- **ZnO Nanoparticles suspension preparation**

ZnO Nanoparticles used in this study were purchased from Nano research Lab PVT Limited. Sizes of Nanoparticles are 20-30nm, 40-50nm, 60-80nm, 80-100nm Nanoparticles were directly suspended in de-ionized water and dispersed ultrasonic vibration (100W, 40 KHz) for 10 minutes at lab of Department of Molecular and cellular Engineering, SHUATS. Small magnetic bars were placed in the suspension for stirring through Ultra sonicator to avoid aggregation of the particles and several suspensions of concentration range up to maximum possible limit were tried for uniform particle dispersion, stability and clear suspension (trial and error method) 3 concentrations of each size Nanoparticles (30, 60, 80 PPM) were selected for their evaluation in Buck wheat seed germination and growth study.

3. Result and Discussion

- **Analysis of Variance in Field conditions**

Analysis of Variance for Effect of particle size and concentration of Zinc oxide Nanoparticles on Growth, Yield parameters in Buckwheat (*Fagopyrum esculentum* L.) under late sowing conditions in Eastern Uttar Pradesh region. In Table 1.

- **Analysis of Variance in Seedling Parameters**

The Analysis of Variance for Effect of particle size and concentration of Zinc oxide Nanoparticles on Seedling parameters, Chlorophyll Content, protein Content, Dehydrogenize Activity in Buckwheat (*Fagopyrum esculentum L.*) under late sowing conditions in Eastern Uttar Pradesh region. In Table 2.

Table: 1 Analysis of variance for different characters in Buckwheat under field conditions

S.No	Characters	Mean sum of squares		
		Treatments (d.f = 13)	Replications (d.f = 3)	Error (d.f = 24)
01	Plant Height at 30 DAS	3.53*	0.21	0.35
02	Plant Height at 85 DAS	18.52*	5.21	5.59
03	Days to 50% Flowering	4.11*	0.45	0.62
04	Number of Branches	0.79*	0.00	0.01
05	Leaf Surface Area	8.46*	0.02	0.19
06	Seeds per Plant	622.29*	21.23	10.43
07	Seed Yield per Plot	14.75*	0.14	0.05
08	Seed Yield per ha	0.15*	0.00	0.00
09	Test Weight	9.15*	0.02	0.50
10	Economic Yield	14.75*	0.14	0.05
11	Biological Yield	65.72*	1.22	0.49
12	Harvest Index	31.76*	1.21	1.28

Table: 2 Analysis of variance for different characters in Buckwheat under field conditions

S.No	Characters	Mean Sum Of Squares (MSS)	
		Treatments (d.f = 13)	Error (d.f = 39)
01	Germination percent	34.5*	3.07
02	Root Length	7.63*	0.067
03	Shoot length	4.79*	2.20
04	Seedling length	9.5*	2.25
05	Fresh Weight of seedling	0.3*	0.07
06	Dry Weight of seedling	0.06*	0.01
07	Seedling Vigor Index 1	156025.15*	16460.61
08	Seedling Vigor Index 2	2657.13*	60.73
09	Chlorophyll Content	1.192*	0.003
10	Protein Content	7.16*	0.036
11	Dehydrogenize activity	0.077*	0.00

***indicates significance at 5%**

3.1 Physiological Observations:

At 30 DAS significantly higher Plant Height was observed in T_1 seeds treated with ZnO Nanoparticles of 20-30mm (30ppm for 8hrs) with 23.45cm and the lowest was recorded in T_0 (20.16 cm**)**.At 85 DAS Plant Height was significantly higher in (T_1) seeds treated with ZnO Nanoparticles of 20-30nm (30ppm for 8hrs) with 91.36cm, Followed by T_4 is 90.89 cm. Lowest Plant Height was observed in T_0 with 84.14cm.Days to First Flowering that was recorded during the experimental crop growth, showing a significant better performance in the seeds that are primed with ZnO Nanoparticles of size 20-30 nm(30 PPM for 8hrs)T_1 with 26.11 DAS Showig least DAS for 50% flowering and followed by T_6 with 26.47 DAS. A lowest day to 50%Flowering was observed in T_0 with 29.71 DAS.From The present data on Leaf surface area that was recorded during the experimental crop growth, showing a significant higher leaf surface area in the seeds that are primed with ZnO Nanoparticles of size 20-30 nm(80 PPM for 8hrs) T_3 with 22.37nmthat is followed by T_6 with 22.11nm. Lowest Leaf Surface area was observed in T_0 with 17.72nm. Number of Primary Branches that was recorded during the experimental crop growth, showing a significant high number of branches in the seeds that are primed with ZnO Nanoparticles of size 20-30 nm(30 PPM for 8hrs) T_1 with 4.43 branches and followed by T_4 with 4.28 branches . Lowest number of branches was observed in T_0 with 2.84 branches. Number of seed per plant that was recorded during the experimental crop growth, shows a significant high number of seeds per plant in T_1 with ZnO Nanoparticles of size 20-30 nm(30 PPM for 8hrs) with 142 seeds, followed by T_4 with 139 seeds. Lowest number of seeds per plant was observed in T_0 with 101 seeds.Seed yield per plot that was recorded shows a significant high Performance in T_1 with ZnO Nanoparticles of size 20-30 nm(30 PPM for 8hrs) with 11.87g that is followed by T_4 with11.28g. Lowest seed yield per plot was observed in T_0 with 5.54g.Seed Yield per Hectare that was recorded showed a significant high performance in T_1 with ZnO Nanoparticles of size20-30 nm(30 PPM for 8hrs) with 1.19 t/ha that is followed by T_4 with1.13 t/ha. Lowest seed yield per hectare was observed in T_0 with 0.55 t/ha.Test Weight that was recorded showing a significant high Performance in the seeds that are primed with ZnO Nanoparticles of size 20-30 nm(80 PPM for 8hrs) T_3 with 27.34g that is followed by T_6 with 27.19 g . Lowest Test Weight was observed in T_0 with 22.49g.ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) $T_1$with 11.87g That is followed by T_4 with 11.28 g. The lowest Economic Yield was obtained in T_0 with 5.54g.Biological Yield was obtained in T_1withZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) with 32.76 g and that is followed by T_4 with 32.14 g and T_0 with 19.33 g was the lowest among all other treatments.Harvest Index was obtained in T_1 with ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) with 36.23% and that is followed by T_4 with 35.09 % and T_0 with 28.41% was the lowest among all other treatments.

Table 3: Mean performance of Effect of particle size and concentration of Zinc oxide Nanoparticles on growth, yield parameters in buckwheat

Treatments	PH 85 DAS	DFF	LSA	NPB	NSP	SYP	SYH	TW	EY	BY	HI
T_0	84.14	29.71	17.72	2.84	101.28	5.54	0.55	22.49	5.54	19.33	28.41
T_1	91.36	26.11	21.79	**4.43**	**142.39**	**11.87**	**1.19**	25.31	**11.87**	**32.76**	**36.23**
T_2	89.49	26.68	20.83	3.84	127.59	10.45	1.05	26.83	10.45	30.77	33.98
T_3	87.16	27.83	**22.37**	3.31	109.35	7.14	0.71	**27.34**	7.14	25.17	28.51
T_4	**90.89**	28.14	21.38	**4.28**	**139.54**	11.28	**1.13**	24.46	**11.28**	**32.14**	**35.09**
T_5	88.61	26.87	20.64	3.67	121.73	9.67	0.97	26.58	9.67	28.75	33.64
T_6	85.73	26.47	**22.11**	3.19	106.68	6.84	0.68	**27.19**	6.84	23.75	28.80
T_7	**90.46**	**29.12**	18.76	4.11	135.38	**11.09**	1.11	23.15	11.09	31.64	35.05
T_8	88.24	28.46	20.37	3.51	117.46	9.25	0.93	23.87	9.25	27.66	33.44
T_9	85.26	27.19	18.12	3.06	105.73	6.39	0.64	26.17	6.39	21.24	30.08
T_{10}	90.16	**29.38**	18.57	3.97	130.24	10.73	1.07	22.64	10.73	31.12	34.50
T_{11}	87.73	28.74	19.43	3.43	111.29	8.43	0.84	23.69	8.43	26.32	32.06
T_{12}	84.43	27.58	17.81	2.98	103.21	6.04	0.60	25.67	6.04	20.63	29.32
F Test	S	S	S	S	S	S	S	S	S	S	S
S.EM (±)	1.37	0.45	0.05	0.05	1.86	0.12	0.01	0.41	0.12	0.4	0.56
CD 5%	3.99	1.32	0.14	0.14	5.44	0.36	0.04	1.19	0.36	1.17	1.63

DAS: Days after sowing; PH: Plant height; LSA: Leaf Surface Area; NPB: Number of Primary branches; DFF: Days to First flowering; NSP: Number of seeds per plant; SYP: Seed Yield per plot; SYH: Seed yield Per Hectare; TW: Test Weight; BY: Biological yield; HI: Harvest Index

3.2 Seedling Observations:

Germination percent shows variation significantly among all treatments. T_1 seeds treated with ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) Showed higher germination percent than other treatments (95.63%) and Followed by T_4 with (94.57%). The lowest germination percent was observed in (T_0) with 85.74%.Root Length shows variation significantly among all treatments. T_1 seeds treated with ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) Showed higher Root Length than other treatments (14.57cm) and Followed by T_4 with (14.25cm). The lowest Root Length was observed in T_0 with (10.69cm).Shoot length shows variation significantly among all treatments. T_3 seeds treated with ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) Showed higher shoot length than other treatments (11.57cm) and Followed by T_6 with (11.41cm). The lowest shoot length was observed in T_0 with (8.53cm).Seedling length shows variation significantly among all treatments. T_1 seeds treated with ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) Showed higher seedling length than other treatments (24.26cm) and Followed by T_4 with (24.18cm). The lowest seedling length was observed in T_0 with (19.22cm).Higher Seedling Fresh Weight recorded in the seeds treated with ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) of $T_3$with 2.39g than other treatments that is followed by T_6 with 2.11g. The lowest seedling fresh Weight was observed in T_0 with (1.25g).Higher Seedling Dry Weight recorded in the seeds treated with ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) of T_3 with 0.80g than other treatments that is Followed by T_6 with 0.79g. The lowest seedling Dry Weight was observed in T_0 with (0.43g).Seedling Vigor Index -I was observed in seeds treated with (T_1) ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) with 2369.25. and that is followed by T_4 with 2286.31. The lowest Vigor Index -I was recorded in T_0 with 1648.02.Seedling Vigor Index-II was observed in seeds treated with (T_3) ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) with 72.67 and that is followed by T_6 with 71.07. The lowest Vigor Index -II was recorded in T_0 with 37.23.Seed Density is shown that ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) (T_3) is significantly higher (0.8) over all other treatments and that is followed by T_1, $T_2$and T_4 with Seed Density (0.7).The lowest Seed Density was observed in T_0 (0.2).From the data that was recorded, Seeds primed with treatment $T_1$of ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) shows significantly higher electrical conductivity with (0.327)that is followed by T_6 with (0.259). The lowest electrical conductivity was recorded in T_0 with (0.153). From the data that was recorded, Seeds primed with treatment T_1 of ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) had shown higher Seed metabolic efficiency with (1.01) and that is followed by T_3 with (0.97). The lowest seed metabolic efficiency was recorded in T_0 with (0.84).

Table 4: Mean performance of Effect of particle size and concentration of Zinc oxide Nanoparticles on Seedling parameters, Chlorophyll Content, Protein Content, Dehydrogenize activity in buckwheat

Treatments	GP	RL	SL	Se.L	FW	DW	VI-I	VI-II	SD	EC	SME	CC	PC	DE
T_0	85.74	10.69	8.53	19.22	1.25	0.43	1648.02	37.23	0.2	0.153	0.84	1.21	9.61	0.593
T_1	**95.63**	**14.57**	10.19	**24.76**	1.85	0.60	**2369.25**	58.16	0.7	**0.327**	**1.01**	2.65	**13.59**	0.795
T_2	92.68	13.41	11.35	24.76	2.09	**0.76**	**2295.35**	**70.58**	**0.7**	0.199	0.97	2.31	12.74	0.935
T_3	90.29	11.63	**11.57**	23.20	**2.19**	**0.80**	2096.00	**72.67**	**0.8**	0.227	**0.974**	**2.84**	11.21	**0.996**
T_4	**94.57**	**14.25**	9.92	**24.18**	1.73	0.59	2286.31	56.05	0.7	0.164	0.931	2.43	13.35	0.744
T_5	91.87	12.89	11.16	24.05	2.05	0.71	2208.19	65.20	0.6	0.208	0.963	2.26	12.48	0.887
T_6	89.62	11.35	**11.41**	22.76	**2.11**	0.79	2039.39	71.07	0.8	0.259	0.88	**2.70**	10.93	**0.968**
T_7	93.68	14.09	8.75	22.84	1.56	0.49	2143.52	45.89	0.5	0.186	0.94	1.81	13.11	0.634
T_8	91.38	12.60	9.75	22.35	1.67	0.56	2043.62	51.23	0.6	0.214	0.942	2.18	11.89	0.705
T_9	87.74	10.97	10.86	21.835	1.96	0.67	1915.51	59.26	0.4	**0.273**	0.92	1.42	10.57	0.846
T_{10}	93.27	13.76	8.61	22.37	1.39	0.44	2080.03	41.80	0.4	0.193	0.91	1.5	**12.98**	0.611
T_{11}	90.76	12.35	9.41	21.76	1.63	0.50	1975.94	46.01	0.5	0.22	0.85	2.02	11.46	0.657
T_{12}	87.48	10.83	10.48	21.31	1.92	0.63	1863.54	55.27	0.3	0.301	0.85	1.35	9.82	0.823
F Test	S	S	S	S	S	S	S	S				S	S	S
S.EM (±)	0.87	0.13	0.74	0.75	0.13	0.05	64.14	4.95				0.028	0.095	0.007
CD (p=0.05)	2.5	0.37	2.13	2.15	0.38	0.15	184.19	14.23				0.08	0.273	0.021

GP-Germination Percentage; RL-Root length; SL-Shoot length; SeL-Seedling length; FW-Fresh weight ; DW-Dryweight; VI-I-Vigour index-I; VI-II-Vigour index-II; SD-Seed density; SME- Seed metabolic efficiency ;EC-Electrical conductivity

3.3 Biochemical analysis:

Chlorophyll Content which was recorded as significant higher in seeds Primed with (T_3) ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) with 2.84 %. However that is followed by T_6 with (2.64%).The lowest chlorophyll Content was observed in T_0 with (1.21%).Protein Content which was recorded as significant higher in seeds treated with (T_1) ZnO Nanoparticles of size 20-30nm (30PPM for 8hrs) with 13.59. However that is followed by T_4 with protein Content (13.35). The Lowest protein Content was observed in $T_0$with (9.61).Dehydrogenize Activity. It is clear that seeds treated with ZnO Nanoparticles of size 20-30nm (80PPM for 8hrs) (T_3) performed better and is significantly higher over all other treatments with 0.996 and that is followed by T_6 with 0.968 respectively and lowest dehydrogenize activity was recorded in T_0 with 0.593.

Table 5: Mean performance of Effect of particle size and concentration of Zinc oxide Nanoparticles on Chlorophyll Content, Protein Content, Dehydrogenize activity in buckwheat

Treatments	CC	PC	DE
T_0	1.21	9.61	0.593
T_1	2.65	**13.59**	0.795
T_2	2.31	12.74	0.935
T_3	**2.84**	11.21	**0.996**
T_4	2.43	13.35	0.744
T_5	2.26	12.48	0.887
T_6	**2.70**	10.93	**0.968**
T_7	1.81	13.11	0.634
T_8	2.18	11.89	0.705
T_9	1.42	10.57	0.846
T_{10}	1.5	**12.98**	0.611
T_{11}	2.02	11.46	0.657
T_{12}	1.35	9.82	0.823
F Test	S	S	S
S.EM (±)	0.028	0.095	0.007
CD (p=0.05)	0.08	0.273	0.021

CC-Chlorophyll Content ; DE-Dehydrogenize Activity ; PC-Protein Content

Discussion

In present investigation was conducted to know the Effect of particle Size and Concentration of ZnO Nanoparticles on Growth, Yield and Seedling parameters in Buckwheat crop as experimental results proved the beneficial effect of Nanoparticles, some logical explanation has been discussed in detail in favor to particle size and concentration . Buckwheat seeds treated with ZnO Nanoparticles Buckwheat seeds to germination test under laboratory conditions along with untreated seeds (control). The results pertaining to seed germination and early seedling growth of seeds treated with ZnO Nanoparticles are given in table 4.The seeds treated with ZnO Nanoparticles treated Buckwheat seeds showed significantly more seed germination and seedling performance with respect radical and shoot growth as compared to control (untreated) seed

Tables 3 and 4 show that ZnO Nanoparticles sized 20 to 30, 40 to 50, 60 to 80, and 80 to 100 nm significantly improved vegetative growth, triggered early flowering, and seed output in treated Buckwheat plants.

Deore *et al.*, (2010) studied the effect of liquid organic fertilizer supplemented with chelated micronutrients (containing Zn) on red pepper and observed increased growth and yield. Similarly **Datir *et al.*, (2010)** studied the effect of organically chelated micronutrients (containing Zn) on growth and productivity in okra and reported increased growth and yield due to chelated micronutrient fertilizer. Also reported application of amino acid chelated micronutrients (containing Zn) for enhancing growth and productivity in chilli (*Capsicum annum* L.)

Prasad *et al.*, (2012) suggested that ZnO Nanoparticles are absorbed by plants to a larger extent as compared to ZnSO4 bulk. They also observed beneficial effects of Nanoparticles sin enhancing plant growth, development and yield in peanut at lower doses, but a thigher concentration ZnO Nanoparticles were detrimental just as the bulk nutrients. Similar results were noted by **Racuciu and Creanga (2007)** on plant growth in *Zea mays* L. at early onto genetics tags due to treatment of magnetic Nanoparticles coated.

ZnO nanoparticles also increase the expression and activity of the nitrate reductase and carbonic anhydrase, two enzymes which plays key role in nitrogen uptake and chlorophyll synthesis respectively. These all indicates the positive effect on maize by ZnO nanoparticles which increase in root and shoot length ultimately leads to increase in vigour index **(Sarkosh *et al*.,2022, Solanki *et al*.,2018)** Zinc (Zn) is an essential micronutrient that acts as a co-factor for many enzymes and facilitates protein folding. It is involved in numerous vital processes such as photosynthesis, antioxidant defense system and disease resistance **(Alloway., 2008).**

Raskar and Laware (2014) Studied the effect of ZnO Nanoparticles on seed germination and seedling growth in Onion and observed that seed germination increased at lower concentrations of ZnO Nanoparticles but decreased at higher concentrations**. Yilmaz *et al*., (1998**) studied the effect of seed zinc content on grain yield and zinc concentration of wheat growth in zinc-deficient cal carious soils. They observed that wheat plants emerging from seeds with low Zn content had poor seedling vigor and field establishment on Zn-deficient soils. **Rengel and Graham (1995)** Reported from a pot culture experiment on wheat plants that increasing seed zinc content from 0.25 g to 0.70 g per seed significantly improved root and shoot growth under Zn deficiency

As we know zinc is a micronutrient its requirement in plant is limited therefore concentration of zinc oxide Nanoparticles plays a major role. Higher concentrations increase the availability zinc ions to the plant and helps in its growth and development. Increase in germination is due to increased absorption of Nanoparticles into the seed coat and consequently the increase in the water absorption, light, activity of rubisco enzyme. Light activates the PIL-5 protein destruction pathway and leads to an increase in the biosynthesis and degradation of GA which, in turn, results in rapid seedling growth **(Iziy et al.,2019)**

By treating the seeds with zinc oxide Nanoparticles responsible for activating the enzymes by fusing with the formation of chlorophyll in most plants and accelerate company growth hormone, such as tryptophan this increase in production is the main place to store carbohydrates in plants, carbohydrates are grains that eventually led to increase number of seeds per plant as a source, and storage carbohydrates, and increase the yield of maize. Increase in seed index might be due to zinc plays a key role as an activator of enzymes in plants and it involved in the biosynthesis of auxin, which produces more cells and dry matter that in turn will be stored in seeds as sink. Thus the increase in the kernels is more expected and results are obtained good or might be due to the proper and adequate supply of Zn increased the uptake of N during the grain formation stage and ultimately improved the seed index of maize **Kumar *et al*., (2021).**

The mobility of Nanoparticles is known to be very high which ensure the phloem transport and ensure the nutrients to reach all the parts of plants and there by affecting the conversion rate to higher dry matter accumulation which ultimately leads to increase in harvest index. The results are significantly in accordance with **(Poornima *et al.*, 2019).** The seed nutrient quality status are estimated the seed treatment with ZnO Nanoparticles improved protein content compared to untreated seeds zinc enhances cation- exchange capacity of the roots, which in turn enhances surface absorption of essential nutrients, especially nitrogen which is responsible for higher protein content **(Tarafdar *et al*.,2013).** The improvement in the zinc content is due to small size with large area which leads to absorption of zinc and turn its concentration in seeds **(Reddy 2014.)**

Deore and Laware (2011) studied effect of liquid organic fertilizer supplemented with organically chelated micronutrients (Zn, Cu and Fe) in red pepper and tomato and observed beneficial effects on seed germination and early seedling growth, they attributed these favorable effects to the availability of micronutrients to seeds during seed germination. Zinc enhances cat ion exchange capacity of the roots, which in turn enhances absorption of essential nutrients, especially nitrogen which is responsible for higher protein content. Zinc plays vital role in carbohydrate and proteins metabolism as well as it controls plant growth hormone i.e IAA. Zn is also an essential component of dehydrogenase, proteinase, and peptides enzymes as well as promotes starch formation, seed maturation and production. These facts indicate that the availability Zn to seed or high Zn content with in the seeds during seed germination has very important physiological roles in seed germination and early seedling growth. The higher percent seed germination

Conclusion

- Among various treatments T_1 in which seeds are treated with 30PPM of size 20nm-30nm performed better in terms of Plant Height-85DAS, Days to first flowering, Number of branches/Plant, Leaf surface area, Number of Seeds/plant, Seed yield per Plot, Seed yield Per Hectare, Economic Yield, Biological Yield, Harvest Index and seeds treated with 80PPM of size 20nm-30nm (T_3) performed better in terms of Leaf surface area and Test Weight. When compared with the Control (T_0) which has shown lowest performance in all parameters.Among all the treatments T_1in which seeds treated with 30PPM of Zinc oxide (ZnO) of 20-30nm size for 8hrs has shown higher level of Germination Percentage, Root Length, Seedling length, Vigor Index-1, Electric conductivity, seed metabolic efficiency, Protein Content, and Seeds Treated With 80PPM of Size 20nm-30nm (T_3) Shown high level of Shoot Length, Fresh Weight, Dry Weight, Vigor Index-II Seed Density, Chlorophyll Content and Dehydrogenize Activity. when compared with the Control(T_0) which has shown lowest performance in all parameters

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