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

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## 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

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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).

*Keywords: 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. Foliar application of ZnO in either forms increased leaf area, shoot dry weight, chlorophyll content. ZnO nanoparticle-treated plants showed higher pigment content than TiO2 nanoparticle-treated plants (Amita Hajra and Naba Kumar Mondal 2017). The extent of increase in chlorophyll content and shoot weight was greater as nano-sized ZnO was applied to the normal form. The results show that the nano-sized particles of ZnO compared to normal form has greater effect on biomass production of sunflower plants.(Abd El-Rahman et al.2020). 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. Nanoparticles were capable of penetrating living plant tissues when sprayed on plant leaves, and migrated from leaves to different parts of plant. Higher the particle size lower was Nanoparticles penetration. Particle size less than 20nm may be preferred to spray (Tarafdar *et al.,*2012) The plants treated with ZnO Nanoparticles at low concentration showed better growth and flowered 12-14 days earlier than the control. Treated plants showed significantly higher values for seeded fruit per umbel, seed weight per umbel and 1000 seed weight over control plants (S.L.Laware and Shilpa Raskar 2014). 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. Accumulation of zinc increases with increasing Zn doses in both wheat and maize, with higher doses being in wheat than in maize.(A. Srivastav *et al.,* 2021). The plants sprayed with ZnO Nanoparticles at the concentration of 500 and 1000 ppm showed the increased leaf length, width, surface area and colour of leaf samples when compared to control leaf samples (Kisan. B. *et al.,* 2015).

Treatment of nanoscale ZnO at 1000 ppm concentration promoted both seed germination and seedling vigor and in turn showed early establishment in soil manifested by early flowering and higher leaf chlorophyll content (Prasad T.N.V.K.V et al. 2013).

Zinc is an essential micronutrient that acts as co factor for many enzymes and facilitates protein folding. It is involved in numerous vital processes such as photosynthesis, antioxidant defense system and diseases resistance (Alloway *et al*.,2008).

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.

## 1.1 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. MATERIALS AND METHODS

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.

## 2.1 Methodology

### 2.1.1 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. RESULTS AND DISCUSSION

## 3.1 Result

### 3.1.1 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.

### 3.1.2 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.

### 3.1.3 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 $T_1$withZnO 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.

### 3.1.4 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).

### 3.1.5 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 1. Analysis of variance for different characters in Buckwheat under field conditions**

| S.No | Characters | Mean sum of squares | | |
|---|---|---|---|---|
| | | Treatments (d.f = 12) | Replications (d.f = 2) | 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 laboratory conditions**

| S.No | Characters | Mean Sum of Squares (MSS) | |
|---|---|---|---|
| | | Treatments (d.f = 12) | Error (d.f = 24) |
| 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%*

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T0 | 84.14 | 29.71 | 17.72 | 2.84 | 101.28 | 5.54 | 0.55 | 22.49 | 5.54 | 19.33 | 28.41 |
| T1 | 91.36 | 26.11 | 21.79 | 4.43 | 142.39 | 11.87 | 1.19 | 25.31 | 11.87 | 32.76 | 36.23 |
| T2 | 89.49 | 26.68 | 20.83 | 3.84 | 127.59 | 10.45 | 1.05 | 26.83 | 10.45 | 30.77 | 33.98 |
| T3 | 87.16 | 27.83 | 22.37 | 3.31 | 109.35 | 7.14 | 0.71 | 27.34 | 7.14 | 25.17 | 28.51 |
| T4 | 90.89 | 28.14 | 21.38 | 4.28 | 139.54 | 11.28 | 1.13 | 24.46 | 11.28 | 32.14 | 35.09 |
| T5 | 88.61 | 26.87 | 20.64 | 3.67 | 121.73 | 9.67 | 0.97 | 26.58 | 9.67 | 28.75 | 33.64 |
| T6 | 85.73 | 26.47 | 22.11 | 3.19 | 106.68 | 6.84 | 0.68 | 27.19 | 6.84 | 23.75 | 28.80 |
| T7 | 90.46 | 29.12 | 18.76 | 4.11 | 135.38 | 11.09 | 1.11 | 23.15 | 11.09 | 31.64 | 35.05 |
| T8 | 88.24 | 28.46 | 20.37 | 3.51 | 117.46 | 9.25 | 0.93 | 23.87 | 9.25 | 27.66 | 33.44 |
| T9 | 85.26 | 27.19 | 18.12 | 3.06 | 105.73 | 6.39 | 0.64 | 26.17 | 6.39 | 21.24 | 30.08 |
| T10 | 90.16 | 29.38 | 18.57 | 3.97 | 130.24 | 10.73 | 1.07 | 22.64 | 10.73 | 31.12 | 34.50 |
| T11 | 87.73 | 28.74 | 19.43 | 3.43 | 111.29 | 8.43 | 0.84 | 23.69 | 8.43 | 26.32 | 32.06 |
| T12 | 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*

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T0 | 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 |
| T1 | 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 |
| T2 | 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 |
| T3 | 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 |
| T4 | 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 |
| T5 | 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 |
| T6 | 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 |
| T7 | 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 |
| T8 | 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 |
| T9 | 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 |
| T10 | 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 |
| T11 | 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 |
| T12 | 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 | S | S |
| S.EM (±) | 0.87 | 0.13 | 0.74 | 0.75 | 0.13 | 0.05 | 64.14 | 4.95 | 0.05 | 0.015 | 0.014 | 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 | 0.16 | 0.12 | 0.11 | 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*

**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 |
|---|---|---|---|
| T0 | 1.21 | 9.61 | 0.593 |
| T1 | 2.65 | 13.59 | 0.795 |
| T2 | 2.31 | 12.74 | 0.935 |
| T3 | 2.84 | 11.21 | 0.996 |
| T4 | 2.43 | 13.35 | 0.744 |
| T5 | 2.26 | 12.48 | 0.887 |
| T6 | 2.70 | 10.93 | 0.968 |
| T7 | 1.81 | 13.11 | 0.634 |
| T8 | 2.18 | 11.89 | 0.705 |
| T9 | 1.42 | 10.57 | 0.846 |
| T10 | 1.5 | 12.98 | 0.611 |
| T11 | 2.02 | 11.46 | 0.657 |
| T12 | 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*

## 3.2 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.

## 4. 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 $T_1$in 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

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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