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*RESEARCH PAPER*

# Root characteristics studies in tropical sugarbeet as influenced by genotypes and fertilizer levels

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**Abstract :** The field experiments were conducted at ARS, Mudhol, University of Agricultural Sciences, Dharwad in order to study the response of sugarbeet genotypes and fertilizer N and K levels on root characters of sugarbeet during *Rabi* season of 2011-12 and 2012-13. The experiment was laid out in Split Plot Design. Three genotypes *viz*., SZ -35, PAC 60008 and Magnolia were assigned to main plot and five N:$K_2O$ levels to sub plots *viz*., 100, 120, 140, 160 and 180 kg N:$K_2O$ $ha^{-1}$. The crop was raised under irrigated condition. The experimental results revealed that, the performance Magnolia genotype was found superior over SZ 35 and PAC 60008 with respect root diameter, fresh weight and volume. The lengthier roots were observed in SZ 35. Among the fertilizer N: $K_2O$ levels application of 160:160 kg N:$K_2O$ $ha^{-1}$ was found to be significant compared to other levels. The genotype Magnolia applied with of N and $K_2O$ @ 160:160 kg $ha^{-1}$ recorded significantly higher root volume, diameter and root fresh weight compared to other treatment combinations.

**Key Words :** Root volume, Root diameter, Root length, Tropical sugarbeet, Root fresh weight

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## INTRODUCTION

Tropical sugarbeet [*Beta vulgaris* (L.) ssp. *vulgaris var. altissima* Doll] is a biennial sugar producing root crop, grown in temperate countries and ranks second important sugar crop after sugarcane, producing annually about 40 per cent of sugar production all over the world (Leilah *et al*., 2005). From the past studies it was observed that, with the recent development of tropicalized hybrids of sugarbeet, it is possible to raise the crop in tropical and subtropical areas in India. Hence, sugarbeet can be considered as an additional supplementary source for production of white sugar as well as ethanol in India. Ethanol produced from sugarcane and sugarbeet being used as biofuel, which is environment-friendly and blended with gasoline. In Brazil 20-24 per cent of ethanol is blended with gasoline, while in the USA it is 10 per cent.

Tropical sugarbeet can be cultivated even in land which has gone wastes due to high salinity and the water requirement of sugarbeet is one third of sugarcane crop. Further, as the harvesting period coincide with March to June, the human resource of sugar factory in the off season could be efficiently utilized for processing of

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sugarbeet by the sugar mills, which facilitates in continuous functioning of the sugar mills. More over in the recent past the Indian sugar factories faced with danger of drastic reduction in sugarcane production due to persistent drought. Our attempt is not to replace sugarcane but to supplement.

The introduction of a crop to a regional cropping system requires information concerning its performance under local environmental conditions and the sustainability of cropping system can be achieved through choosing of suitable environment and cultivar/genotype for each crop (Prosba-Bialczyk *et al.*, 2001).

Nitrogen is often the most limiting factor in crop production and application of fertilizer nitrogen results in higher biomass yield (Blumenthal *et al.*, 2008). Increasing sugarbeet production per unit area could be achieved by application of suitable potassium fertilizer treatment (El-Harriri and Gobarh, 2001). Potassium fertilizer is one of the main factors which restricts agricultural production and decreases yields of sugarbeet upto 30-40 per cent (Bernard *et al.*, 2006). Thus, application of suitable fertilizers, such as nitrogen and potassium may be one of the favourable factors for the higher production of sugarbeet.

The root development can be measured by root characteristics studies such as root length, root diameter, root volume and root fresh weight, which are the most important yield attributes deciding the yield of crop. In this regard, the experiment was conducted with one of the objectives to study the root characters. The details of the experiment and methodology followed are presented under the sub heading Materials and Methods.

## MATERIAL AND METHODS

Field experiments were conducted at the Agricultural Research Station, Mudhol,University of Agricultural Sciences, Dharwad, located in the Northern Dry Zone (Zone 3) of Karnataka during *Rabi* season of 2011-12 and 2012-13 to study the effect of sugarbeet genotypes to nitrogen and potassium levels. The soil of the experimental site was clay. The basal application of poultry manure as source of organic manure was done @ 3.5 t $ha^{-1}$ fifteen days prior to planting by broadcasting and immediate incorporation in the field by tractor drawn plough. The sugarbeet genotypes were obtained from private organizations. PAC 60008 and SZ 35 were obtained from "The Ses Vander Have" Pvt. Ltd., Belgium and the Magnolia variety was obtained from "JK Agro-Genetics Pvt. Ltd.," Seed Division, Pune. The experiment was laid out in split plot design and replicated thrice. Three sugarbeet genotypes were assigned to main plot and five N and $K_2O$ levels to subplots. 60 kg $P_2O_5$ $ha^{-1}$ was common to all treatments as basal application and N and K in four splits *viz.*, 10 per cent N and $K_2O$ basal application, 30 per cent N and $K_2O$ at 30 DAS, 30 per cent N and $K_2O$ at 50 DAS and 30 per cent N and $K_2O$ at 90 DAS. Seed rate of 3.0 to 3.6 kg $ha^{-1}$ was used with the spacing of 75 cm x 10 cm. Experiment was conducted during 2011-12 and 2012-13 (2 years) and the pooled data is presented in this paper. The crop was sown during 13th and 12th August of 2011 and 2012, respectively during two experimental years and harvested after 180 days. The crop was raised under irrigated condition and other recommended package of practices for the crop was used as per the recommendation. Root diameter was calculated by using the following formula as suggested by Rice (1999). Root length was recorded after uprooting of fresh root, which was poured with water well in advance. The root volume was measured by water displacement technique. The observation on root fresh weight also recorded at different intervals. The treatment details are given below.

**Treatment details :**

*Main plot* : Sugarbeet genotypes
$V_1$: SZ 35
$V_2$: PAC 60008
$V_3$: Magnolia.
*Sub plot*: Levels of N and K
$F_1$: 100:100 kg N:$K_2O$ $ha^{-1}$
$F_2$: 120:120 kg N:$K_2O$ $ha^{-1}$
$F_3$: 140:140 kg N:$K_2O$ $ha^{-1}$
$F_4$: 160:160 kg N:$K_2O$ $ha^{-1}$
$F_5$: 180:180 kg N:$K_2O$ $ha^{-1}$.

## RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

**Root length :**

The results pertaining to root length are presented in Table 1. Significantly lengthier roots were found in SZ 35 (19.4, 30.7, 35.3 and 37.1 cm at 45, 90, 135 DAS and at harvest, respectively). The shortest root length was noticed in Magnolia (16.6, 26.5, 31.2 and 34.2 cm at 45, 90, 135 DAS and at harvest, respectively) and was of par with PAC 60008 at all the stages except at harvest. As the fertilizer levels increased from 100 kg $ha^{-1}$ to 180 kg $ha^{-1}$ the root length increased gradually. The lengthier roots were noticed with the application N and $K_2O$ @ 180 kg $ha^{-1}$ (20.4, 31.8, 37.0 and 39.7 cm during 45, 90, 135 DAS and at harvest, respectively) and was found to be at par with 160 kg $ha^{-1}$ application. The lowest root length was recorded with application N and $K_2O$ @ 100 kg $ha^{-1}$ (15.7, 24.8, 29.4 and 31.5 cm at 45, 90, 135 DAS and at harvest, respectively) and was found to be at par with 120 kg $ha^{-1}$ during 45 and 135 DAS. Root length was not significant due to the interaction effect of genotypes and different N and $K_2O$ levels at all the crop growth stages.

The lengthier (Table 1) and conical shaped roots were obtained in the SZ 35 which might be due to the faster cell division and elongation at the growing point of root compared to Magnolia. Also, the lengthier roots in a particular genotype may be due to its genetic potential. The results of the study are in line with the findings of Balakrishnan and Selvakumar (2008). It could be noticed that increasing N and K fertilizers rates significantly increased root growth. These results appear to be mainly

**Table 1: Root length of sugarbeet at different growth stages as influenced by genotypes, nitrogen and potassium levels (Pooled)**

| N and K level (F) | Root length (cm) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 45 DAS | | | | 90 DAS | | | | 135 DAS | | | | At harvest (180 days) | | | |
| | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | |
| | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M |
| $F_1$ | 16.9 | 16.1 | 14.3 | 15.7 | 26.5 | 25.7 | 22.4 | 24.8 | 30.3 | 30.1 | 27.8 | 29.4 | 32.1 | 31.7 | 30.8 | 31.5 |
| $F_2$ | 18.3 | 16.8 | 14.9 | 16.7 | 30.3 | 26.9 | 25.2 | 27.5 | 34.0 | 31.7 | 29.8 | 31.8 | 36.1 | 33.0 | 32.3 | 33.8 |
| $F_3$ | 18.6 | 18.4 | 17.0 | 18.0 | 30.5 | 28.1 | 27.4 | 28.7 | 35.6 | 31.9 | 32.1 | 33.2 | 37.0 | 34.4 | 34.0 | 35.1 |
| $F_4$ | 20.6 | 19.5 | 18.2 | 19.4 | 32.5 | 28.8 | 28.3 | 29.9 | 38.0 | 34.2 | 32.5 | 34.9 | 39.3 | 37.5 | 35.8 | 37.5 |
| $F_5$ | 22.7 | 20.0 | 18.5 | 20.4 | 33.8 | 32.3 | 29.4 | 31.8 | 38.8 | 38.3 | 33.9 | 37.0 | 41.2 | 40.2 | 37.8 | 39.7 |
| Mean (M) | 19.4 | 18.2 | 16.6 | 18.1 | 30.7 | 28.3 | 26.5 | 28.5 | 35.3 | 33.2 | 31.2 | 33.3 | 37.1 | 35.4 | 34.2 | 35.5 |
| | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D.(P=0.05) | |
| V | 0.33 | | 1.08 | | 0.77 | | 2.51 | | 0.71 | | 2.31 | | 0.17 | | 0.54 | |
| F | 0.44 | | 1.25 | | 0.67 | | 1.91 | | 0.86 | | 2.44 | | 0.42 | | 1.20 | |
| VxF | 0.76 | | NS | | 1.17 | | NS | | 1.49 | | NS | | 0.73 | | NS | |

$F_1$ : 100:100 kg N:$K_2O$ $ha^{-1}$ $F_4$ : 160:160 kg N:$K_2O$ $ha^{-1}$ $V_1$ : SZ 35 NS : Non-significant
$F_2$ : 120:120 kg N:$K_2O$ $ha^{-1}$ $F_5$ : 180:180 kg N:$K_2O$ $ha^{-1}$ $V_2$ : PAC 60008 DAS : Days after sowing
$F_3$ : 140:140 kg N:$K_2O$ $ha^{-1}$ $V_3$ : Magnolia M : Mean

**Table 2: Root diameter of sugarbeet at different growth stages as influenced by genotypes, nitrogen and potassium levels (Pooled)**

| N and K level (F) | Root diameter (cm) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 45 DAS | | | | 90 DAS | | | | 135 DAS | | | | At harvest (180 days) | | | |
| | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | |
| | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M |
| $F_1$ | 3.29 | 3.62 | 3.59 | 3.50 | 5.37 | 5.52 | 5.67 | 5.52 | 6.13 | 6.88 | 8.00 | 7.00 | 7.08 | 7.84 | 8.76 | 7.89 |
| $F_2$ | 3.83 | 4.06 | 3.63 | 3.84 | 5.54 | 6.47 | 6.15 | 6.05 | 6.42 | 7.29 | 8.17 | 7.29 | 7.47 | 8.24 | 9.07 | 8.26 |
| $F_3$ | 4.05 | 4.29 | 4.74 | 4.36 | 5.74 | 6.62 | 6.90 | 6.42 | 7.23 | 7.66 | 8.36 | 7.75 | 7.99 | 8.46 | 9.39 | 8.61 |
| $F_4$ | 4.89 | 5.12 | 5.29 | 5.10 | 6.80 | 7.33 | 8.31 | 7.48 | 7.79 | 8.66 | 9.41 | 8.62 | 8.97 | 9.33 | 9.78 | 9.36 |
| $F_5$ | 4.16 | 4.34 | 5.19 | 4.56 | 6.01 | 7.14 | 8.16 | 7.10 | 7.41 | 8.05 | 9.15 | 8.20 | 8.11 | 8.86 | 9.53 | 8.83 |
| Mean (M) | 4.04 | 4.29 | 4.49 | 4.27 | 5.89 | 6.62 | 7.04 | 6.52 | 7.00 | 7.71 | 8.62 | 7.77 | 7.92 | 8.55 | 9.30 | 8.59 |
| | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | |
| V | 0.09 | | 0.28 | | 0.15 | | 0.48 | | 0.10 | | 0.33 | | 0.06 | | 0.20 | |
| F | 0.13 | | 0.37 | | 0.23 | | 0.64 | | 0.16 | | 0.47 | | 0.09 | | 0.27 | |
| VxF | 0.23 | | NS | | 0.39 | | NS | | 0.28 | | NS | | 0.16 | | 0.46 | |

$F_1$ : 100:100 kg N:$K_2O$ $ha^{-1}$ $F_4$ : 160:160 kg N:$K_2O$ $ha^{-1}$ $V_1$ : SZ 35 NS : Non-significant
$F_2$ : 120:120 kg N:$K_2O$ $ha^{-1}$ $F_5$ : 180:180 kg N:$K_2O$ $ha^{-1}$ $V_2$ : PAC 60008 DAS : Days after sowing
$F_3$ : 140:140 kg N:$K_2O$ $ha^{-1}$ $V_3$ : Magnolia M : Mean

due to the role of N in developing root dimensions by increased cell division and/or elongation. The positive effect of N fertilizer might be due to the increased efficiency of N-fertilization in building up metabolites translocations from leaves to developing roots (El-Shahawy *et al.*, 2002).

**Root diameter :**

The data pertaining to root diameter are presented in Table 2. Significantly greater root diameter was recorded in Magnolia (4.49, 7.04, 8.62 and 9.30 cm at 45, 90, 135 DAS and at harvest, respectively) and was at par with PAC 60008 (4.29 and 6.62 cm at 45 and 90 DAS, respectively). However, the lowest root diameter was noticed in SZ 35 (4.04, 5.89, 7.00 and 7.92 cm at 45, 90, 135 DAS and at harvest, respectively). The genetic constituent of genotype influenced growth and development process of Magnolia, that include a vigorous and extensive root system, increased crop growth rate during vegetative growth period, more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the modified tap root and larger leaf area index during the vegetative growth period. The performance of sugarbeet hybrids/ genotype may vary from one place to other due to the varying climatic conditions. The yield characters and yield of different sugarbeet hybrids were also compared by Balakrishnan and Selvakumar (2008) and reported that Cauvery and Indus hybrids were comparable to Shubra.

The highest root diameter was recorded with application N and $K_2O$ @ 160 kg ha$^{-1}$ (5.10, 7.48, 8.62 and 9.36 cm at 45, 90, 135 DAS and at harvest, respectively) and was at par with $F_5$ only during 135 DAS. The lowest root diameter (3.50, 5.52, 7.00 and 7.89 cm, respectively) was observed with application of N and $K_2O$ @ 100 kg ha$^{-1}$ at all the above stages of plant growth. The interaction effect was found significant only at harvest. The highest root diameter was observed with application of N and $K_2O$ @ 160 kg ha$^{-1}$ to Magnolia (9.78 cm) or N and $K_2O$ @ 180 kg ha$^{-1}$ to Magnolia (9.53 cm) or application of N and $K_2O$ @ 160 kg ha$^{-1}$ to PAC 60008 genotype (9.33 cm). The lowest root diameter was noticed in SZ 35 treated with N and $K_2O$ @ 100 kg ha$^{-1}$ (7.08 cm).

The direct effect of K on yield is less marked than of N, which itself constitutes a part of the organic matter synthesized during growth. Also, K uptake is much affected by N level and in most cases, K is more effective at higher N level, which is the case especially to modern high yielding varieties (El-Shafai, 2000 and Mack *et al.*, 2007). The interaction between N and K were small at low rates, but became more important at high rates and the best returns from one nutrient were obtained at high rates of others. Root crops especially, have a high K requirement. It is commonly observed that root or tube enlargement is depressed relatively more than leaf development, when K is in short supply (Inal, 1997). These results were also in line with the findings of Abdel-Motagally and Attia (2009).

**Root volume :**

Data pertaining to root volume are presented in Table

**Table 3: Root volume of sugarbeet at different growth stages as influenced by genotypes, nitrogen and potassium levels (Pooled)**

| N and K level (F) | Root volume (cm$^3$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 45 DAS | | | | 90 DAS | | | | 135 DAS | | | | At harvest (180 days) | | | |
| | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | |
| | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M |
| $F_1$ | 38.3 | 48.4 | 68.4 | 51.7 | 226.8 | 270.0 | 340.6 | 279.2 | 266.9 | 395.9 | 511.0 | 391.2 | 331.9 | 491.8 | 730.5 | 518.1 |
| $F_2$ | 62.7 | 83.7 | 90.7 | 79.0 | 258.7 | 332.7 | 455.8 | 349.1 | 357.5 | 409.6 | 611.6 | 459.6 | 392.1 | 526.1 | 806.5 | 574.9 |
| $F_3$ | 78.0 | 101.5 | 100.8 | 93.4 | 316.7 | 442.0 | 473.4 | 410.7 | 416.1 | 497.3 | 635.0 | 516.1 | 501.8 | 623.5 | 876.1 | 667.1 |
| $F_4$ | 115.3 | 139.5 | 125.7 | 126.8 | 397.7 | 489.2 | 605.8 | 497.6 | 560.9 | 602.1 | 754.9 | 639.3 | 671.9 | 815.2 | 951.2 | 812.8 |
| $F_5$ | 85.9 | 108.0 | 116.9 | 103.6 | 343.6 | 470.0 | 505.0 | 439.5 | 494.0 | 539.8 | 693.9 | 575.9 | 552.0 | 673.0 | 919.3 | 714.7 |
| Mean (M) | 76.1 | 96.2 | 100.5 | 90.9 | 308.7 | 400.8 | 476.1 | 395.2 | 419.1 | 488.9 | 641.3 | 516.4 | 489.9 | 625.9 | 856.7 | 657.5 |
| | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | |
| V | 0.84 | | 2.75 | | 2.10 | | 6.85 | | 2.94 | | 9.58 | | 4.64 | | 15.13 | |
| F | 1.11 | | 3.15 | | 5.18 | | 14.73 | | 7.00 | | 19.92 | | 8.17 | | 23.24 | |
| VxF | 1.92 | | 5.46 | | 8.97 | | 25.51 | | 12.13 | | 34.49 | | 14.16 | | 40.26 | |

$F_1$ : 100:100 kg N:$K_2O$ ha$^{-1}$
$F_2$ : 120:120 kg N:$K_2O$ ha$^{-1}$
$F_3$ : 140:140 kg N:$K_2O$ ha$^{-1}$
$F_4$ : 160:160 kg N:$K_2O$ ha$^{-1}$
$F_5$ : 180:180 kg N:$K_2O$ ha$^{-1}$
$V_1$ : SZ 35
$V_2$ : PAC 60008
$V_3$ : Magnolia
NS : Non-significant
DAS : Days after sowing
M : Mean

3. The Magnolia recorded significantly higher root volume (100.5, 476.1, 641.3 and 856.7 $cm^3$ at 45, 90, 135 DAS and at harvest, respectively) wherein the lowest was observed in SZ 35 (76.1, 308.7, 419.1 and 489.9 $cm^3$ at all the above stages, respectively). The increase in root volume was due to increased dimension of root, which might be due to increased nutrient uptake and resulted in greater accumulation of photosynthates.

The highest root volume was recorded with the application N and $K_2O$ @ 160 kg $ha^{-1}$ (126.8, 497.6, 639.3 and 812.8 $cm^3$ at 45, 90, 135 DAS and at harvest, respectively) and the lowest was recorded with application of N and $K_2O$ @ 100 kg $ha^{-1}$ (51.7, 279.2, 391.2 and 518.1 $cm^3$ at 45, 90, 135 DAS and at harvest, respectively). Among the interaction effect, significantly higher root volume was recorded in Magnolia treated with application of N and $K_2O$ @ 160 kg $ha^{-1}$ (605.8, 754.9 and 951.2 $cm^3$ at 90, 135 DAS and at harvest, respectively) except at 45 DAS wherein PAC 60008 applied with N and $K_2O$ @ 160 kg $ha^{-1}$ was the highest (139.55 $cm^3$). The lowest root volume was recorded in SZ 35 treated with N and $K_2O$ @ 100 kg $ha^{-1}$ (38.3, 226.8, 266.9 and 331.9 $cm^3$ at 45, 90, 135 DAS and at harvest, respectively). The enhancing effect of nitrogen and potassium fertilization on root diameter and volume may be attributed to the increase in cell size and numbers as a result of increasing division of cells as well as activating accumulation of metabolites in storage roots. These results are in agreement with Sarhan (1998); Sayed *et al.* (1998); El-Hawary (1999) and El-Harriri and Gobarh (2001).

**Root fresh weight :**

Data pertaining to root fresh weight are presented in Table 4. The highest root fresh weight was recorded in Magnolia (159.7, 447.8, 568.0 and 698.0 g $plant^{-1}$ at 45, 90, 135 DAS and at harvest, respectively) and was at par with PAC 60008 only during 90 DAS with the lowest being recorded in SZ 35 (109.7, 369.1, 442.0 and 496.4 g $plant^{-1}$, respectively at 45, 90, 135 DAS and harvest). The higher root fresh weight in Magnolia might be due to increased moisture content and accumulation of photosynthates in the roots.

Root fresh weight increased rapidly as the levels of fertilizers increased from 100 kg $ha^{-1}$ to 160 kg $ha^{-1}$. Significantly higher root fresh weight was recorded with application of N and $K_2O$ @ 160 kg $ha^{-1}$ (192.1, 534.3, 584.6 and 704.0 g $plant^{-1}$ during 45, 90, 135 DAS and at harvest, respectively) and the lowest was noticed with application of N and $K_2O$ @ 100 kg $ha^{-1}$ (81.6, 297.3, 392.5 and 470.6 g $plant^{-1}$ during 45, 90, 135 DAS and at harvest, respectively). The increment of root fresh weight gained by increasing nitrogen and potassium levels may be due to the role of nitrogen in developing root dimensions by increasing division or elongation of cells. Moreover, the role of potassium in activating enzymes is related to the accumulation of carbohydrates.

Interaction effect due to genotypes and N and $K_2O$ levels was found significant at all the stages of plant growth except at 135 DAS. Significantly higher root fresh weight was recorded in Magnolia treated with N and $K_2O$ @ 160 kg $ha^{-1}$ (242.5, 596.0 and 843.4 g $plant^{-1}$ during 45, 90 DAS and at harvest, respectively)

**Table 4 : Root fresh weight of sugarbeet at different growth stages as influenced by genotypes, nitrogen and potassium levels (Pooled)**

| N and K level (F) | Root fresh weight (g $plant^{-1}$) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 45 DAS | | | | 90 DAS | | | | 135 DAS | | | | At harvest (180 days) | | | |
| | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | | Genotype (V) | | | |
| | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M | $V_1$ | $V_2$ | $V_3$ | M |
| $F_1$ | 54.7 | 80.8 | 109.3 | 81.6 | 279.7 | 320.7 | 291.7 | 297.3 | 341.0 | 376.9 | 459.5 | 392.5 | 408.8 | 461.3 | 541.7 | 470.6 |
| $F_2$ | 102.6 | 90.0 | 121.4 | 104.6 | 317.7 | 347.0 | 416.3 | 360.3 | 422.1 | 427.1 | 533.3 | 460.8 | 474.4 | 537.9 | 634.8 | 549.0 |
| $F_3$ | 115.1 | 132.3 | 158.0 | 135.1 | 373.0 | 485.7 | 452.0 | 436.9 | 452.8 | 528.6 | 576.1 | 519.2 | 501.1 | 602.5 | 707.3 | 603.6 |
| $F_4$ | 147.9 | 186.1 | 242.5 | 192.1 | 472.3 | 534.5 | 596.0 | 534.3 | 506.0 | 580.0 | 667.6 | 584.6 | 567.4 | 701.3 | 843.4 | 704.0 |
| $F_5$ | 128.2 | 170.9 | 167.6 | 155.6 | 403.0 | 508.7 | 483.0 | 464.9 | 488.0 | 551.5 | 603.6 | 547.7 | 530.3 | 631.6 | 762.9 | 641.6 |
| Mean (M) | 109.7 | 132.0 | 159.7 | 133.8 | 369.1 | 439.3 | 447.8 | 418.8 | 442.0 | 492.8 | 568.0 | 500.9 | 496.4 | 586.9 | 698.0 | 593.8 |
| | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | | S.E.± | | C.D. (P=0.05) | |
| V | 0.66 | | 2.15 | | 3.28 | | 10.70 | | 7.88 | | 25.71 | | 4.08 | | 13.31 | |
| F | 1.34 | | 3.80 | | 5.17 | | 14.71 | | 8.21 | | 23.35 | | 7.21 | | 20.50 | |
| VxF | 2.31 | | 6.58 | | 8.96 | | 25.48 | | 14.22 | | NS | | 12.49 | | 35.50 | |

$F_1$ : 100:100 kg N:$K_2O$ $ha^{-1}$; $F_2$ : 120:120 kg N:$K_2O$ $ha^{-1}$; $F_3$ : 140:140 kg N:$K_2O$ $ha^{-1}$; $F_4$ : 160:160 kg N:$K_2O$ $ha^{-1}$; $F_5$ : 180:180 kg N:$K_2O$ $ha^{-1}$
$V_1$ : SZ 35; $V_2$ : PAC 60008; $V_3$ : Magnolia
NS : Non-significant; DAS : Days after sowing; M : Mean

wherein SZ 35 treated with 100 kg $ha^{-1}$ recorded the lowest (54.7, 279.7 and 408.8 g $plant^{-1}$ at above stated stages, respectively). The greater improvement in root weight was due to the supply of higher quantities of N and $K_2O$, higher response of the genotype to optimum dose of N and $K_2O$ with increased nutrient use efficiency. Similar findings were also obtained by Leilah *et al*. (2007) and Tawfik *et al*. (2010). This increase in the fertilizer use efficiency resulted in higher yield.

## Conclusion :

Root characteristic studies have shown that application of N and $K_2O$ @ 160 kg $ha^{-1}$ to Magnolia genotype has increased the root growth and development processes. Hence, increase in root fresh weight; diameter and volume increased the yield of crop.

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