The present study was conducted to study the effect of depth of sowing on seedling emergence, and correlation with coleoptile length in advance lines of wheat. The experimental material comprised of 60 wheat genotypes including certain advance lines and released varieties; and was carried out for two consecutive season viz. 2016-17 and 2017-18. These genotypes were categorised into three different coleoptile length groups i.e. short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) coleoptile length on the basis of observation in laboratory. All genotypes were sown at three different depths of 5cm, 7.5cm and 10 cm and replicated twice. The study revealed that the short and medium coleoptile length genotypes had less variation in emergence at all depths whereas the longer coleoptile length genotypes had significantly better field emergence. Coleoptile length was directly proportional to seedling shoot length i.e. short, medium and long coleoptile classes had an average coleoptile length of 7.12 cm, 8.87 cm, and 12.60 cm respectively. Longer coleoptile length class genotypes also had higher SVI I and SVI II i.e. short, medium and long coleoptile classes had an average SV I value of 2051.8, 2198.11 and 2752.33 and SV II value of 42.3, 55.57 and 72.8 respectively. Larger coleoptile length was also in accordance with the higher root surface area, root volume and number of forks which provide genotypes early seedling vigour in stress conditions.

**Keywords**
Coleoptile length, Shoot length, Seed vigour indices, Root surface area, Root volume

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**Abstract**

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**Introduction**

The total land area of India is 329 million hectares of which 144 million hectares is arable land. Of this, 94 million hectares fall under dry lands constituting 65% of dryland and rainfed areas which produce 40% of the total food grains that feeds 40% of the total population. The remaining 50 million hectares constituting 35% of irrigated areas, account for 60% of the crop production. Dryland areas contribute significantly to wheat (*Triticum aestivum* L.) production, amounting to thirty three per cent of wheat production. Enhancing the production of dryland areas seems an attractive way to increase the productivity and production of wheat by introduction of alternate cropping system in rice-wheat areas. New production methodology like conservation agriculture can provide long term solution to all above raised issues. In the dryland area, upper soil moisture is depleted...
very rapidly after the sowing due to higher rate of evaporation. Hence depth of sowing in these areas becomes an important factor for field emergence in semi dwarf varieties of wheat. Thus the coleoptile length of the seedling becomes an important feature for the proper field emergence (Mohan et al., 2013). Similarly, moisture depletion takes place very rapidly with very early sowing of wheat due to presence of high temperature at that time. Thus higher depth of sowing facilitated by longer coleoptile length is of utmost importance for uniform establishment of crop for getting the higher productivity. Hence, higher crop yield is mainly dependent on the rapid and uniform field establishment of crop in the field, which is highly influenced by the sowing depth and the ability of the seedlings to emerge from the soil. Hence, the present study was conducted to study the effect of depth of sowing on seedling emergence, root characters and seed quality parameters in wheat.

**Materials and Methods**

The present study was undertaken during 2016-17 and 2017-18 at Division of Seed Science and Technology, IARI, New Delhi. The experimental material comprised of 60 wheat genotypes which were divided into three categories based on the coleoptile length of lines. These lines were denoted by code name (CLY Number); and are listed along with their respective pedigree (Table 1). The experiment was conducted in pots of size 15 cm diameter and 15 cm depth. Pot was filled with soil representing uniform moisture levels (11-12 %) from various locations in the divisional field. Ten seeds for each genotypes were sown at varying depths of 5 cm, 7.5 cm and 10 cm and was replicated twice. The germination test was conducted as per ISTA 2015. Speed of germination was calculated by the formula as suggested by the Maguire (1962). For measuring the seedling length, ten normal seedlings were selected randomly for measuring root and shoot length and expressed in centimetres (cm). After taking the final count of germination test, 10 normal seedlings from each replication were removed, washed, weighed and dried overnight at 80 ± 1°C. Seedling dry weight was expressed in mg/five seedlings. Vigour indices were calculated by the procedure as suggested by the Abdul-Baki and Anderson, 1973. For measuring coleoptile length, 25 seeds were kept on a moist germination paper with germ end down having 1cm markings on either side of the central line, and kept in upright position at 20ºC in dark and observation was taken on 10th day. Roots obtained at 8th day were separated from shoot by cutting and scanned in root scanner by the latest WinRHIZO software for root length, surface area, root volume and number of forks. In the present investigation the laboratory studies were analyzed by using completely randomized design (CRD). Star Nebula software obtained from website of IRRI was used for the data analysis and correlation between all the important parameters was calculated.

**Results and Discussion**

The coleoptile length of all the 60 genotypes was recorded and categorised as short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) (Table 1). Seed of each genotype was sown in pots under varying sowing depths of 5cm, 7.5 cm, and 10cm and replicated twice. When short coleoptile length genotypes were sown at depths of 5cm, 7.5cm and 10cm depths, average seedling emergence from 5cm and 7.5 cm sowing depths was comparable to some extent i.e. 92.25% and 86.25% but the emergence from 10cm sowing depth was drastically reduced to 58% (Fig. 1). For medium coleoptile length genotypes, average seedling emergence from 5cm and 7.5 cm sowing depths was 97% and 86.75% and the
emergence from 10cm sowing depth was reduced to 70.75 % (Fig. 2). For large coleoptile length genotypes, average seedling emergence from 5cm and 7.5 cm sowing depths was 97.75% and 91%. The emergence from deep sown condition averaged to 83% (Fig. 3) which was quite good as compared to short and medium coleoptile genotypes. Although there was a reduction in seedling emergence but it is sufficient to obtain a good plant stand in field condition. No definite relation could be established between speed of germination and genotypes of three different classes i.e. short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) coleoptile length genotypes. For each class, the speed of germination was 38.70, 38.20 and 39.60 respectively (Table 1). The speed of emergence is mainly dependent on the radical appearance which is a part of root initials, and no effect of GAR Rht genes on root length has been reported till date. Hence this explains the possible cause for non-existence of any definite relation. The coleoptile length was directly proportional to seedling shoot length i.e. short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) coleoptile classes had on an average 7.12 cm, 8.87 cm, and 12.60 cm shoot lengths respectively (Table 1). This provides the long coleoptile genotypes an added advantage of better photosynthesis and dry matter accumulation over the short and medium coleoptile genotypes during early developmental stages and helps in better field establishment.

Similarly, the higher coleoptile length class genotypes had higher seedling vigour Index I and seedling vigour Index II. The short, medium and long coleoptile classes had on an average SV I value of 2051.8, 2198.11 and 2752.33 respectively and SV II values of 42.3, 55.57 and 72.8 respectively (Table 1). Hence, the longer coleoptile genotypes can provide better seedling emergence and ultimately better field establishment. Root biomass study is an efficient and rapid technique for assessment of the crop performance mainly for the initial growth stages which determines the early seedling vigour of crop. Surface area is main root biomass parameter which determines the early seedling vigour in wheat and results of the present study revealed that root surface area of different genotype classes i.e. short, medium and long coleoptile length had an average surface area of 6.23 cm$^2$, 7.52 cm$^2$ and 8.55 cm$^2$ respectively, where longer coleoptile length class genotypes had distinctly larger surface area; which leads to better seedling vigour and seedling establishment (Table 2). Similarly, longer coleoptile length genotypes had distinctly larger root volume than that of short and medium coleoptile length genotypes (Table 2). Root volume is also a major root biomass parameter responsible for early seedling vigour of wheat and from this study it is clearly evident that root volume of different genotype classes i.e. short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) coleoptile length had an average root volume of 0.089 cm$^3$, 0.110 cm$^3$ and 0.131 cm$^3$ respectively (Table 2). Number of forks is an important parameter of root biomass in crops like wheat having fibrous root structure, more is the number of forks more is the absorptive surface and more nutrient uptake results in good seedling establishment. From the study of number of forks, it is clearly evident that number of forks of different genotype classes i.e. short (2.5-4.5 cm), medium (4.6-6.5 cm) and long (6.6-9 cm) coleoptile lengths had an average 37.6, 42.8 and 56.5 number of forks respectively. Higher number of forks in genotypes of long coleoptile length class gives an advantage over other genotype classes and provides an early growth advantage also (Table 2).
Table 1. Seed quality parameters for genotypes categorised under short, medium and long coleoptile length

| Genotypes | Pedigree | Coleoptile Length(cm) | Speed of Germination (cm) | Shoot Length (cm) | Seed Vigour Index I | Seed Vigour Index II |
|-----------|----------|-----------------------|--------------------------|-------------------|--------------------|--------------------|
| **Short coleoptile length genotypes** | | | | | | |
| CLY1642  | 7 EBWYT 504 | 3.64 | 38.75 | 6.80 | 2210 | 41.25 |
| CLY1647  | HD2874/HD2967//43rd IBWSN 1148 | 3.82 | 38.17 | 6.60 | 1964 | 36.26 |
| CLY1648  | HD2874/HD2967//43rd IBWSN 1148 | 3.78 | 40.17 | 7.24 | 2084 | 49.86 |
| CLY1649  | HD2874/HD2967//43rd IBWSN 1087 | 3.80 | 41.00 | 7.44 | 1999 | 38.41333 |
| CLY1650  | HD2874/HD2967//43rd IBWSN 1087 | 3.50 | 37.33 | 6.58 | 1851 | 45.41333 |
| CLY1652  | 10 SBWON-27//PBW 343/DW571 | 3.52 | 37.67 | 6.92 | 1996 | 47.09 |
| CLY1653  | 31ESWYT-113//DW1272/HP1731 | 3.44 | 39.83 | 6.82 | 2020 | 42.88 |
| CLY1656  | 31ESWYT-113//DW1272/HP1731 | 3.76 | 38.60 | 7.26 | 2024 | 50.21333 |
| CLY1659  | 31ESWYT-1473/HWS5028//HD2432/DW1309 | 4.56 | 38.25 | 7.74 | 2151 | 40.78667 |
| CLY1662  | 18 HRWYT 214//HRWYT-229 | 3.56 | 38.42 | 7.62 | 2022 | 37.85667 |
| CLY1664  | 18 HRWYT 214//HRWYT-229 | 3.90 | 36.42 | 6.82 | 2046 | 39.45 |
| CLY1670  | HD 2824//VL804//PBW532//UP2425 | 3.58 | 40.75 | 7.00 | 1981 | 46.07 |
| CLY1679  | EBWYT 60 | 3.54 | 36.42 | 7.00 | 2016 | 35.75 |
| CLY1684  | Recombinant inbred line (RILs) | 3.98 | 37.50 | 7.30 | 1988 | 41.55 |
| CLY1686  | CL1449/PBW343//WL412//Ve//Koel/3/Pes/Mc-II | 3.48 | 39.08 | 7.80 | 1964 | 41.76 |
| CLY1698  | 31 ESWYT 138/CSW23 | 3.80 | 39.90 | 7.00 | 2194 | 43.77333 |
| CLY1708  | PBW343/CL1538//HD2932//HD2189 | 3.98 | 39.42 | 7.04 | 2119 | 29.80667 |
| HD3086   | | 3.60 | 38.17 | 7.72 | 2238 | 43.08333 |
| HD 3117  | | 4.26 | 38.58 | 8.24 | 2113 | 48.78 |
| HD 2967  | | 3.86 | 39.67 | 7.38 | 2056 | 42.63 |
| **Mean** | | **3.77** | **38.70** | **7.12** | **2051.8** | **42.3** |
| **Medium coleoptile length genotypes** | | | | | | |
| CLY1601  | CL2596/K9451/CL882//HD2009 | 5.44 | 37.75 | 9.08 | 2404 | 53.36 |
| CLY1610  | CL2596/K9451/CL882//HD2009 | 5.62 | 40.00 | 9.56 | 2347 | 56.12 |
| CLY1622  | C-32 SAWSN 327 | 5.60 | 38.00 | 9.92 | 2417 | 50.92 |
| CLY1632  | HD2953//HS365 | 5.30 | 40.08 | 9.16 | 2097 | 62.1 |
| CLY1634  | SAWSN 3094 | 5.48 | 37.08 | 9.00 | 2105 | 55.18 |
| CLY1635  | SAWSN 3097 | 5.66 | 35.17 | 7.98 | 2111 | 48.90667 |
| CLY1638  | 18 HRWYT 214 | 5.44 | 38.00 | 9.44 | 2344 | 58.96 |
| CLY1651  | HD2874//HD2967//43rd IBWSN 1087 | 4.86 | 39.92 | 7.78 | 1969 | 46.8 |
| CLY1657  | 31ESWYT-1473/HWS5028//HD2432/DW1309 | 4.96 | 36.00 | 9.30 | 2493 | 48.01333 |
| CLY1676  | SAWSN 3194 | 5.42 | 38.58 | 9.26 | 2216 | 58.66667 |
| CLY1677  | CSISA-HT-EM-37 | 5.32 | 38.17 | 9.06 | 2365 | 51.81333 |
| CLY1678  | SRRSN 6083 | 5.26 | 34.25 | 8.68 | 2135 | 66.50333 |
| CLY1680  | EBWYT 98 | 5.26 | 38.67 | 8.40 | 2049 | 61.64 |
| CLY1681  | EBWYT 81 | 4.96 | 38.08 | 8.46 | 2365 | 60.45 |
| CLY1692  | 31 ESWYT 135//CSW23 | 5.26 | 38.75 | 9.20 | 2083 | 64.72667 |
| CLY1693  | 31 ESWYT 135//CSW23 | 5.04 | 39.17 | 9.36 | 2335 | 65.28 |
| CLY1695  | 31 ESWYT 135//HD2329//WR544/PBW343//NW3041 | 4.82 | 39.00 | 8.70 | 2342 | 59.63 |
| CLY1701  | 31 ESWYT 138//PBW343//PH137//MC-II | 4.82 | 40.42 | 7.14 | 1852 | 45.56 |
Table 2 Root characters for genotypes categorised under short, medium and long coleoptile length

| Genotypes | Surface area (cm²) | Root volume (cm³) | Number of forks |
|-----------|-------------------|------------------|----------------|
| **Short coleoptile length genotypes** | | | |
| CLY1642   | 6.604             | 0.0822           | 34             |
| CLY1647   | 6.814             | 0.0837           | 45             |
| CLY1648   | 6.686             | 0.0992           | 42             |
| CLY1649   | 6.218             | 0.0776           | 31             |
| CLY1650   | 5.076             | 0.0896           | 37             |
| CLY1652   | 5.224             | 0.0783           | 44             |
| CLY1653   | 5.726             | 0.1032           | 40             |
| CLY1656   | 3.78              | 0.1024           | 32             |
| CLY1659   | 5.682             | 0.0678           | 37             |
| CLY1662   | 7.14              | 0.1148           | 35             |
| CLY1664   | 5.65              | 0.0876           | 41             |
| CLY1670   | 6.326             | 0.1058           | 40             |
| CLY1679   | 6.34              | 0.0982           | 33             |
| CLY1684   | 7.476             | 0.0762           | 36             |
| CLY1686   | 6.886             | 0.108            | 43             |
| CLY1698   | 7.126             | 0.0854           | 32             |
| CLY1708   | 7.026             | 0.1056           | 36             |
| Genotype  | Mean (Length) | Standard Deviation | Genotypes |
|-----------|--------------|--------------------|------------|
| HD3086    | 5.876        | 0.0916             | 42         |
| HD 3117   | 5.868        | 0.0712             | 38         |
| HD 2967   | 6.544        | 0.0534             | 34         |
| Mean      | 6.23         | 0.089              | 37.6       |
| **Medium coleoptile length genotypes** |             |                    |            |
| CLY1601   | 7.246        | 0.112              | 43         |
| CLY1610   | 7.654        | 0.114              | 47         |
| CLY1622   | 7.95         | 0.108              | 38         |
| CLY1632   | 6.38         | 0.0991             | 41         |
| CLY1634   | 7.273        | 0.1028             | 45         |
| CLY1635   | 7.158        | 0.1074             | 38         |
| CLY1638   | 8.152        | 0.1268             | 48         |
| CLY1651   | 7.478        | 0.1162             | 50         |
| CLY1657   | 7.132        | 0.0874             | 42         |
| CLY1676   | 7.761        | 0.128              | 46         |
| CLY1677   | 7.864        | 0.119              | 46         |
| CLY1678   | 7.886        | 0.1056             | 36         |
| CLY1680   | 7.486        | 0.1224             | 39         |
| CLY1681   | 7.784        | 0.0982             | 43         |
| CLY1692   | 7.662        | 0.119              | 46         |
| CLY1693   | 7.26         | 0.124              | 42         |
| CLY1695   | 7.378        | 0.1064             | 38         |
| CLY1701   | 8.206        | 0.1023             | 42         |
| CLY1707   | 7.508        | 0.1096             | 42         |
| HD2329    | 7.356        | 0.0983             | 44         |
| Mean      | 7.52         | 0.110              | 42.8       |
| **Long coleoptile length genotypes** |             |                    |            |
| CLY1606   | 8.068        | 0.1196             | 47         |
| CLY1611   | 8.824        | 0.1308             | 53         |
| CLY1612   | 8.816        | 0.137              | 46         |
| CLY1613   | 8.903        | 0.1134             | 49         |
| CLY1615   | 8.982        | 0.1334             | 57         |
| CLY1617   | 8.21         | 0.1098             | 63         |
| CLY1621   | 8.81         | 0.1384             | 54         |
| CLY1630   | 8.212        | 0.1564             | 76         |
| CLY1636   | 7.412        | 0.1384             | 53         |
| CLY1641   | 9.424        | 0.1426             | 62         |
| CLY1644   | 8.418        | 0.1254             | 59         |
| CLY1661   | 8.134        | 0.1342             | 58         |
| CLY1668   | 8.208        | 0.1234             | 60         |
| CLY1683   | 9.208        | 0.1566             | 48         |
| CLY1700   | 8.778        | 0.1346             | 61         |
| CLY1706   | 8.444        | 0.1376             | 55         |
| NP4       | 8.312        | 0.1128             | 56         |
| NP818     | 8.618        | 0.1172             | 47         |
| C 306     | 8.414        | 0.1314             | 59         |
| HDCSW18   | 8.89         | 0.133              | 67         |
| Mean      | 8.55         | 0.131              | 56.5       |
| C.D. at 5%| 0.321917     | 0.445196           | 0.679235   |
Fig. 1 Seedling emergence of short (2.5-4.5 cm) coleoptile length genotypes from different sowing depths

Fig. 2 Seedling emergence of medium (4.6-6.5 cm) coleoptile length genotypes from different sowing depths

Fig. 3 Seedling emergence of long (6.6-9 cm) coleoptile length genotypes from different sowing depths
Hence from above observations it is concluded that longer coleoptile length class had longer emergence and early seedling vigour as compared to short and medium coleoptile length classes.

The study revealed that the short and medium coleoptile length genotypes had less variation in emergence from 5 cm and 7.5 cm depths of sowing.

On the other hand emergence from 10 cm depth was drastically reduced by 34.25% and 28.25% in short coleoptile length genotypes and by 26.25% and 16% in medium coleoptile genotypes respectively from the emergence from 5 cm and 7.5 cm sowing depths. Similar results were found by Amram et al., (2015); Chen et al., (2013); Rebetzke et al., (2005). The study of seedling vigour index and its relationship with the coleoptile length provides conclusive evidence that genotypes with longer coleoptile had greater early seedling vigour in field than short and medium coleoptile length class of genotypes. Similar results were also repeated by Rosyara et al., (2009).

The longer coleoptile length class of genotypes consistently had greater root surface area, root dry weight, root volume and number of forks per seedling which enhanced their capacity to absorb water from deeper soil profile and increasing number of forks also enhance the capacity to increase specific surface area and hence had capacity to perform well in dryland areas and similar findings were repeated by Rosyara et al., (2009).

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