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Research Article
Evaluation of Early Seedling, Root and Grain Yield Components of Spring Wheat Genotypes in Two Sowing Dates

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Abstract

Background and Objective: Cultivars, time of sowing and good early seedling growth are important factors for successful wheat production. The main objective of this study was to assess the genetic variability of heat adaptive traits along with important agronomic traits, among the elite wheat lines with special focus on root traits. **Materials and Methods:** A set of 30 elite spring wheat genotypes were evaluated for root traits, early vigor and grain yield and its attributes at the research farm of Agriculture and Forestry University, Nepal during the wheat growing season 2015/16 under normal (4th Dec, 2015) and late (25th Dec, 2015) sowing conditions. The experiment was conducted in split-plot design with sowing date as main plot treatment and wheat genotypes as sub-plot treatment. Early vigor and root traits were assessed at Zadok's growth stage 12 (2 leaves unfolded). **Results:** There were significant genotypic effects for all the studied characters. Significant differences were observed between two sowing dates for root count, root length, number of grains per spike, thousand kernel weight and grain yield. For root count and length, there was no significant genotypic difference under normal sowing, while there was highly significant genotypic difference in the late sown crop. Vijay had maximum root length in normal sowing i.e., 8.13 cm and SUP152/QUAIU #2 (35th ESWYT115) had maximum root length in late sowing i.e., 7.30 cm. The mean grain yield was 2.23 t ha^{-1} in normal and 1.13 t ha^{-1} in late sown condition. ND643/2*WBLL1//KACHU (35th ESWYT114) had maximum grain yield i.e., 3.19 t ha^{-1} in normal whereas Gautam had maximum grain yield (1.96 t ha^{-1}) in late sowing. **Conclusion:** Significant genotypic differences for root count and root length under late sowing indicated that genotypes exhibit significant difference at seedling stage when some stress conditions are provided rather than growing under normal condition. So, selection for seedling root traits under stress conditions should be prioritized in future breeding programs for developing moisture stress tolerant wheat cultivars.

Key words: Root count, root length, early vigor, grain yield and attributes

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Wheat (*Triticum aestivum* L.), the world's most important and widely adapted crop in terms of area and production, contributes more calories and protein to the world's diet than any other food crop[1]. In Nepal, it is the third largest crop after rice (*Oryza sativa* L.) and maize (*Zea mays* L.). It is the major cereal crop grown in winter season. Considering the diverse wheat production environments of Nepal and the unique taste and quality requirement by the farmers, the current availability of improved wheat varieties to the farmers is limited[2].

Time of planting is one of the most important non-monetary inputs for optimizing the growth according to prevailing agro-climatic conditions and genotypes. The performance of wheat varies with different dates of planting[3]. Under late sown conditions, wheat crop is exposed to heat stress during the critical growth stages, i.e. flowering and grain filling and cause production losses. Yields of late-seeded wheat are reduced by as much as 40% in Nepal[4]. Studies have shown that there is an optimum date for planting, which is followed by an almost linear decline in yield after that date. Also, there are differences between varieties: some genotypes are more stable over a range of planting dates than others[5].

The differential response of genotypes for seedling associated traits like seedling fresh and dry weight, number of roots and root length under varying stress conditions will be of great help to plant breeders for developing varieties suitable for different temperature stress environments. The growth and function of roots are essential for crop productivity especially under abiotic stresses such as drought and heat[6]. The number and length of roots at early seedling stage can be useful in assessing the crop growth and yield potential at the maturity stage. Roots have been intensively studied for over 100 years but little is known about root dynamics despite their importance, as root systems are difficult to access and observe under field conditions. The present study is therefore aimed at assessing the genotypic performance of elite spring wheat under normal and late sown conditions, with special focus on root traits.

MATERIALS AND METHODS

Plant materials and field layout: Thirty bread wheat genotypes were included in this study (Table 1). They were obtained from the Agriculture Botany Division NARC, Khumaltar, Nepal. The plant materials once tested at Khumaltar on 35th Elite Spring Wheat Yield Trial (35th ESWYT) included 23 elite lines and 5 lines from 5th Harvest Plus Yield Trial (5th HPYT) originated from CIMMYT, Mexico and 2 Nepalese commercial varieties, namely; Vijay and Gautam. The experiment was conducted in split-plot design with sowing date as main plot treatment and wheat genotypes as sub-plot treatment. The main plot treatment consisted of two sowing dates; normal (December 4, 2015) and late (December 25, 2015). Altogether, there were 60 treatments, each replicated three times.

Early vigor and root traits: They were assessed at Zadok's growth stage 12 (2 leaves unfolded). It consisted of seedling fresh weight and dry weight, root count and root length. Ten seedlings per plot were taken for assessing these traits. Seedlings sampled for this purpose were carefully collected by uprooting which was facilitated by loosening of the soil below the plant with a spatula. As soon as the seedlings were collected, the root portion was cleaned in a running tap water to remove soil particles and other inert substances. After cleaning, blotting paper was used to absorb an excess of water from the seedlings. After carefully soaking water, the average fresh weight of seedling (attached kernel removed) was measured in milligrams using an electronic balance. The average number of primary (main) roots per seedling was counted. The average root length was measured in centimeters from the initiation point of root (scutellum) to the tip of the longest root. The average dry weight of seedling was measured as the constant weight reached after drying at 70°C for 24 or more hours in a well ventilated oven. It was weighed in milligrams using an electronic balance.

Grain yield and its attributes: Ten plants were selected randomly from a plot and plant height was measured with a meter scale in centimeters from the soil surface up to the tip of apical spikelet excluding awns at the time of maturity. Ten spikes of ten randomly selected plants from each plot were hand threshed to count the number of grains per spike. After harvesting and sun drying, 500 random seeds from each plot were counted and weighed. The value was then converted to thousand kernel weight. For grain yield, plants from whole plot were harvested separately for each treatment and sun dried. The weight of grains per plot was recorded in grams and grain yield was calculated in tons per hectare. Moisture content of the grain for each plot was measured using a moisture meter and hence, the actual grain yield was calculated using the Eq.:

Table 1: List of wheat genotypes grown for the field experiment

Trt.	Genotypes	Cross/pedigree
1	Vijay	-
2	Gautam	-
3	35th ESWYT104	MISR 1
4	35th ESWYT105	MUNAL #1
5	35th ESWYT106	BECARD #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ
6	35th ESWYT109	KACHU//KIRITATI/2*TRCH
7	35th ESWYT110	KACHU/CHONTE
8	35th ESWYT111	KIRITATI//HUW234+LR34/PRINIA/3/BAJ #1
9	35th ESWYT112	MUTUS//ND643/2*WBLL1
10	35th ESWYT114	ND643/2*WBLL1//KACHU
11	35th ESWYT115	SUP152/QUAIU #2
12	35th ESWYT118	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/5/CNO79//PF70354/MUS/3/PASTOR/4/BAV92/6/ND643/2*WBLL1
13	35th ESWYT119	BAJ #1/KISKADEE #1
14	35th ESWYT120	CHEWINK #1/MUTUS
15	35th ESWYT121	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/2*MUNAL
16	35th ESWYT123	QUAIU #1/2*SUP152
17	35th ESWYT129	CHYAK1*2/3/HUW234+LR34/PRINIA//PFAU/WEAVER
18	35th ESWYT138	BLOUK #1/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/MUNAL #1
19	35th ESWYT139	BABAX/LR42//BABAX*2/3/PAVON 7S3, +LR47/4/ND643/2*WBLL1/5/BABAX/LR42//BABAX*2/3/PAVON 7S3, +LR47
20	35th ESWYT140	QUAIU #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW/KAUZ/6/BECARD
21	35th ESWYT141	CHIBIA//PRLII/CM65531/3/FISCAL/4/DANPHE #1/5/CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92
22	35th ESWYT143	KACHU*2/CHONTE
23	35th ESWYT145	ND643/2*WBLL1//2*KACHU
24	35th ESWYT147	FRANCOLIN #1*2//ND643/2*WBLL1
25	35th ESWYT148	BECARD//KIRITATI/2*TRCH/3/BECARD
26	5th HPYT402	BAJ #1
27	5th HPYT403	KACHU #1
28	5th HPYT414	FRANCOLIN #1/7/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES/5/T.SPELTA PI348599/6/REH/HARE//2*BCN/3/CROC_1/ AE.SQUARROSA (213)//PGO/4/HUITES
29	5th HPYT420	NELOKI/3/IWA 8600211//2*PBW343*2/KUKUNA
30	5th HPYT438	TRAP#1/BOW/3/VEE/PJN//2*TUI/4/BAV92/RAYON/5/KACHU#1/6/TOBA97/PASTOR/3/T.DICOCCON PI94624/AE.SQUARROSA(409)//BCN/4/BL 1496/MILAN//PI 610750

$$\text{Grain yield (GY)} = \frac{100 - \text{MC}}{100 - \text{SM}} \times \text{Plot yield}$$

Where:

GY = Grain yield (t ha^{-1})

MC = Moisture content of grain

SM = Standard moisture content of wheat grain (12%)

Statistical analysis: Analysis of variance and mean comparison between genotypes based on LSD was done by using RStudio software package. One way ANOVA was carried for combined analysis of variables (sowing dates, genotypes and interaction effect) as a split plot design in 1% ($p<0.01$) and 5% ($p<0.05$) levels of significance.

RESULTS

Analysis of variance detected significant genotypic effects for all the studied characters whereas significant differences were observed between two sowing dates for root count, root length, plant height, grains per spike, thousand kernel weight and grain yield (Table 2). There was significant interaction effect of genotypes and sowing date for root length, thousand kernel weight and grain yield.

Seedling fresh and dry weight: There was no effect of wheat genotypes for seedling fresh weight in normal as well as late sown and for dry weight in normal sown condition whereas a significant genotypic effect ($p<0.05$) for seedling dry weight in late sowing was detected (Table 3). The mean seedling fresh weight of wheat genotypes grown under normal and late sown conditions was 194.08 and 186.19 mg, respectively. Seedling fresh weight was in the range of 147.35-241.48 mg in normal and 128.82-231.88 mg in late sowing. In normal sown condition, mean seedling dry weight was 31.18 mg with Vijay (36.68 mg) having the highest and 35th ESWYT143 (24.90 mg) having the lowest dry weight. Likewise, Gautam had the highest dry weight (36.92 mg) and 5th HPYT403 had the lowest (20.16 mg) in late sown condition with an average of 28.15 mg.

Table 2: Mean squares from ANOVA of different traits of wheat crop as influenced by sowing date and genotypes (2015/2016)

Sources	Df	SFW	SDW	RC	RL	PH	NGPS	TKW	GY
Replication	2	447.8	18.86	0.95	0.18	134.09	89.24	17.50	0.025
Sowing date (A)	1	2800.2	413.69	12.80*	43.90*	1561.03**	1802.47**	2594.34**	54.970**
Error (a)	2	13628.6	173.85	0.41	1.30	4.16	16.70	9.11	0.065
Genotypes (B)	29	2443.5**	54.70**	1.04**	1.22*	98.38**	106.22**	104.83**	0.941**
A×B	29	723.2	14.69	0.25	1.13*	27.15	31.04	55.61**	0.596**
Error (b)	116	1084.7	20.81	0.31	0.72	22.55	49.23	9.36	0.072

SFW: Seedling fresh weight, SDW: Seedling dry weight, RC: Root count, RL: Root length, PH: Plant height, NGPS: Number of grains per spike, TKW: Thousand kernel weight and GY: Grain yield. *Significant in 5% level, **Significant in 1% level

Table 3: Mean values of seedling fresh weight (SFW), seedling dry weight (SDW), root count and root length of 30 wheat genotypes in normal and late sown conditions (2015/2016)

	SFW (mg)		SDW (mg)		Root count		Root length (cm)	
Genotypes[g]	Normal	Late	Normal	Late	Normal	Late	Normal	Late
Vijay	241.48	208.67	36.68	32.74^{a-d}	4.66	4.33^{ab}	8.13	6.30^{abc}
Gautam	226.68	231.88	34.40	36.92^{a}	5.00	4.66^{a}	7.53	6.33^{abc}
35th ESWYT104	208.06	204.10	32.30	35.65^{ab}	4.00	3.00^{d}	6.93	5.43^{c-h}
35th ESWYT105	209.08	186.96	35.35	31.53^{a-e}	4.00	4.33^{ab}	6.00	6.06^{b-e}
35th ESWYT106	151.38	193.92	26.01	28.06^{c-f}	4.33	3.33^{cd}	6.33	4.80^{gh}
35th ESWYT109	210.68	199.60	34.13	30.04^{a-e}	4.33	4.00^{abc}	6.20	5.83^{c-g}
35th ESWYT110	165.68	161.50	27.44	24.96^{efg}	4.66	4.00^{abc}	5.93	5.43^{c-h}
35th ESWYT111	180.16	170.21	30.24	25.82^{c-g}	4.33	3.33^{cd}	7.23	5.83^{c-g}
35th ESWYT112	172.76	188.66	27.48	27.46^{c-g}	4.00	3.33^{cd}	6.20	6.30^{abc}
35th ESWYT114	180.48	192.64	28.20	29.58^{a-e}	3.66	3.33^{cd}	6.70	5.60^{c-h}
35th ESWYT115	228.28	189.30	34.79	27.78^{c-f}	4.33	4.33^{ab}	7.33	7.30^{a}
35th ESWYT118	224.91	179.94	33.42	24.62^{efg}	4.33	4.00^{abc}	7.03	6.23^{a-d}
35th ESWYT119	179.37	198.80	31.80	25.24^{d-g}	3.66	3.00^{d}	6.26	5.76^{c-g}
35th ESWYT120	198.54	203.01	29.89	29.20^{b-e}	4.00	3.00^{d}	6.20	5.00^{e-h}
35th ESWYT121	217.58	225.75	34.57	33.28^{abc}	4.66	4.00^{abc}	6.23	7.10^{ab}
35th ESWYT123	190.58	209.62	31.54	29.13^{b-e}	5.00	4.33^{ab}	7.86	4.86^{fgh}
35th ESWYT129	199.90	192.77	33.15	27.86^{c-f}	4.33	4.33^{ab}	6.26	5.96^{b-f}
35th ESWYT138	164.04	190.46	27.43	30.06^{a-e}	4.00	3.66^{bcd}	6.46	5.43^{c-h}
35th ESWYT139	183.28	148.58	30.68	24.26^{efg}	4.33	3.33^{cd}	6.20	5.53^{c-h}
35th ESWYT140	194.34	159.03	31.48	25.64^{d-g}	4.00	4.33^{ab}	6.93	6.30^{abc}
35th ESWYT141	202.71	181.50	31.44	29.26^{b-e}	4.66	4.00^{abc}	6.23	5.53^{c-h}
35th ESWYT143	147.35	128.82	24.90	21.06^{fg}	4.00	3.66^{bcd}	6.83	5.10^{d-h}
35th ESWYT145	166.72	178.62	29.08	25.63^{d-g}	4.33	3.33^{cd}	7.30	4.60^{h}
35th ESWYT147	202.99	170.58	29.92	25.64^{d-g}	4.00	3.33^{cd}	7.36	5.13^{d-h}
35th ESWYT148	200.70	195.38	32.20	28.88^{b-e}	4.00	4.00^{abc}	6.66	6.13^{b-e}
5th HPYT402	220.26	189.69	35.02	31.09^{a-e}	4.33	4.00^{abc}	6.76	6.00^{b-f}
5th HPYT403	169.32	145.24	27.67	20.16^{g}	3.33	3.00^{d}	6.23	5.36^{c-h}
5th HPYT414	191.24	173.64	29.35	25.65^{d-g}	4.00	3.00^{d}	6.06	5.30^{c-h}
5th HPYT420	189.76	199.68	31.46	28.20^{b-f}	4.33	3.66^{bcd}	6.23	5.93^{c-g}
5th HPYT438	204.06	187.17	33.42	29.09^{b-e}	5.33	4.00^{abc}	8.03	5.56^{c-h}
Grand mean	194.08	186.19	31.18	28.15	4.26	3.73	6.72	5.73
SEM±	19.22	18.81	2.59	2.67	0.34	0.31	0.56	0.41
F-statistic	ns	ns	ns	1.96*	ns	2.70**	ns	2.31**
CV (%)	17.15	17.49	14.41	16.43	13.81	14.27	14.40	12.38
$LSD_{0.05}$	ns	ns	ns	7.56	ns	0.87	ns	1.16

Means within a column followed by the same letter (s) were not significantly different according to LSD test at 5% level. *Significant in 5% level, **Significant in 1% level and ns: Non-significant

Root count and length: For root count and root length, genotypes did not vary among them in normal sowing but highly significant difference ($p<0.01$) was observed among genotypes within late sown crop (Table 3). It indicated the effect of moisture stress on genotypes and how they vary among each other when they are sown beyond the normal planting time. The mean root count was >4 in normal and >3 in late sown condition. Similarly, the root length of wheat genotypes ranged from 5.93-8.13 cm with a mean value of 6.72 cm in normal sown condition and it ranged from 4.60-7.30 cm in late sown condition with a mean value of 5.73 cm. Vijay had maximum and 35th ESWYT110 had

Table 4: Mean values of plant height, number of grains per spike (NGPS), thousand kernel weight (TKW) and grain yield of 30 wheat genotypes in normal and late sown conditions (2015/2016)

	Plant height (cm)		NGPS		TKW (g)		Grain yield (t ha^{-1})	
Genotypes[g]	Normal	Late	Normal	Late	Normal	Late	Normal	Late
Vijay	94.80^{a}	83.53^{ab}	31.66^{h}	30.13	45.42^{abc}	42.04^{a}	2.91^{a-d}	1.83^{abc}
Gautam	94.43^{ab}	86.56^{a}	46.06^{b-f}	44.73	47.66^{ab}	41.20^{a}	2.97^{abc}	1.96^{a}
35th ESWYT104	81.03^{d-g}	71.70^{ijk}	42.26^{b-g}	44.93	40.10^{c-f}	28.34^{g-k}	2.20^{f-i}	1.13^{f-j}
35th ESWYT105	81.53^{d-g}	80.00^{b-e}	42.86^{b-g}	41.00	28.17^{kl}	26.98^{h-k}	2.34^{efg}	1.36^{d-g}
35th ESWYT106	78.53^{e-h}	78.83^{b-g}	41.33^{c-g}	33.20	28.68^{kl}	32.15^{c-g}	1.29^{lm}	1.02^{h-l}
35th ESWYT109	77.90^{fgh}	75.90^{d-i}	51.06^{ab}	40.20	42.88^{bcd}	32.08^{c-g}	2.60^{b-f}	1.20^{e-j}
35th ESWYT110	83.96^{c-g}	79.66^{b-f}	48.66^{a-d}	42.80	34.64^{f-j}	34.48^{bcd}	2.33^{efg}	1.28^{d-i}
35th ESWYT111	80.13^{d-h}	74.20^{f-k}	43.06^{b-g}	39.93	31.67^{jkl}	28.79^{g-k}	1.47^{klm}	0.96^{i-n}
35th ESWYT112	78.60^{e-h}	68.76^{k}	56.00^{a}	41.73	26.70^{l}	30.12^{d-i}	2.26^{e-h}	0.74^{l-o}
35th ESWYT114	82.76^{c-g}	77.03^{c-i}	48.26^{a-e}	46.33	45.31^{abc}	30.75^{d-h}	3.19^{a}	1.12^{f-j}
35th ESWYT115	91.06^{abc}	78.06^{b-h}	41.40^{c-g}	39.00	41.97^{cde}	31.98^{c-g}	2.46^{c-f}	0.75^{l-o}
35th ESWYT118	85.30^{b-f}	77.76^{c-h}	36.06^{gh}	30.86	33.60^{g-k}	33.75^{b-e}	1.31^{klm}	0.95^{j-n}
35th ESWYT119	86.73^{a-f}	74.56^{e-j}	50.46^{abc}	39.46	44.63^{abc}	33.26^{c-f}	2.57^{b-f}	1.32^{d-h}
35th ESWYT120	82.13^{c-g}	77.63^{c-h}	45.33^{b-g}	41.06	37.57^{d-i}	29.42^{e-j}	2.10^{f-j}	1.43^{def}
35th ESWYT121	83.56^{c-g}	78.53^{b-g}	38.33^{fgh}	32.80	38.04^{d-h}	28.08^{g-k}	1.81^{g-k}	0.97^{i-n}
35th ESWYT123	79.36^{d-h}	79.13^{b-g}	45.26^{b-g}	31.73	38.74^{d-h}	37.80^{ab}	1.80^{h-l}	1.92^{ab}
35th ESWYT129	85.46^{a-f}	78.56^{b-g}	47.60^{a-f}	38.80	48.86^{a}	26.29^{ijk}	2.88^{a-d}	0.61^{op}
35th ESWYT138	80.30^{d-g}	77.56^{c-h}	45.13^{b-g}	43.26	44.73^{abc}	28.05^{g-k}	3.08^{ab}	1.42^{def}
35th ESWYT139	80.23^{d-g}	76.06^{d-i}	41.93^{b-g}	35.60	40.52^{cde}	26.88^{h-k}	1.60^{j-m}	0.96^{i-n}
35th ESWYT140	78.16^{e-h}	69.40^{ijk}	40.06^{d-h}	37.80	31.68^{jkl}	26.25^{ijk}	1.68^{i-m}	0.35^{p}
35th ESWYT141	86.06^{a-f}	80.86^{a-d}	46.40^{a-f}	37.60	38.11^{d-h}	25.40^{jk}	2.33^{efg}	1.08^{g-k}
35th ESWYT143	70.80^{h}	76.50^{d-i}	38.66^{e-h}	36.06	33.34^{h-k}	29.51^{e-j}	1.19^{m}	0.76^{k-o}
35th ESWYT145	81.03^{d-g}	78.60^{b-g}	41.46^{b-g}	36.46	40.31^{cde}	33.65^{b-e}	1.49^{klm}	1.60^{bcd}
35th ESWYT147	82.32^{c-g}	75.46^{d-i}	49.00^{a-d}	38.73	32.10^{i-l}	24.86^{k}	2.26^{e-h}	0.67^{nop}
35th ESWYT148	85.23^{b-f}	73.80^{g-k}	49.86^{abc}	39.60	44.53^{abc}	29.25^{f-k}	2.43^{def}	0.74^{l-o}
5th HPYT402	84.03^{c-g}	72.66^{h-k}	46.60^{a-f}	33.20	38.98^{d-g}	33.75^{b-e}	2.91^{a-d}	1.50^{cde}
5th HPYT403	74.83^{gh}	73.60^{g-k}	43.66^{b-g}	28.40	36.94^{e-j}	31.42^{d-g}	1.45^{klm}	1.26^{e-j}
5th HPYT414	87.36^{a-e}	80.16^{b-e}	43.40^{b-g}	35.93	42.58^{bcd}	29.86^{e-i}	2.73^{a-e}	1.01^{h-m}
5th HPYT420	84.10^{c-g}	75.36^{d-i}	46.93^{a-f}	44.20	38.06^{d-h}	28.96^{f-k}	2.52^{c-f}	0.68^{mno}
5th HPYT438	88.00^{a-d}	82.60^{abc}	44.73^{b-g}	38.13	42.75^{bcd}	36.14^{bc}	2.89^{a-d}	1.32^{d-h}
Grand mean	82.99	77.10	44.00	38.00	38.64	31.05	2.23	1.13
SEM±	3.31	2.02	3.39	4.62	1.96	1.55	0.19	0.12
F-statistic	2.43**	3.72**	2.08**	ns	9.18**	7.60**	10.28**	11.40**
CV (%)	6.91	4.52	13.21	20.97	8.79	8.66	14.39	17.89
$LSD_{0.05}$	9.37	5.70	9.60	ns	5.53	4.39	0.52	0.33

Means within a column followed by the same letter (s) were not significantly different according to LSD test at 5% level. *Significant in 5% level, **Significant in 1% level and ns: Non-significant

minimum root length in normal sown while 35th ESWYT115 had maximum and 35th ESWYT145 had minimum root length in late sown condition.

Grain yield and its attributes: The mean grain yield was 2.23 t ha^{-1} in normal and 1.13 t ha^{-1} in late sown condition (Table 4). There was 49.32% decrease in grain yield because of delayed sowing. The grain yield ranged from 1.19-3.19 t ha^{-1} in normal and 0.35-1.96 t ha^{-1} in late sowing. For normal sown condition, 35th ESWYT114 (3.19 t ha^{-1}) was the highest grain yielding genotype followed by 35th ESWYT138 (3.08 t ha^{-1}), Gautam (2.97 t ha^{-1}), Vijay (2.91 t ha^{-1}) and 35th ESWYT129 (2.88 t ha^{-1}) and lowest grain yielding genotype was 35th ESWYT143 (1.19 t ha^{-1}) followed by 35th ESWYT106 (1.29 t ha^{-1}) and 35th ESWYT118 (1.31 t ha^{-1}). For late sown condition, Gautam had highest grain yield (1.96 t ha^{-1}) followed by 35th ESWYT123 (1.92 t ha^{-1}) and Vijay (1.83 t ha^{-1}) whereas lowest was recorded on 35th ESWYT140 (0.35 t ha^{-1}), 35th ESWYT129 (0.61 t ha^{-1}) and 35th ESWYT147 (0.67 t ha^{-1}), respectively.

The mean plant height of wheat genotypes was 82.99 cm in normal and 77.10 cm in late sown condition (Table 4). Vijay was tallest in normal sowing (94.80 cm) followed by Gautam (94.43 cm) and 35th ESWYT115 (91.06 cm). The shortest plant height was recorded for 35th ESWYT143 (70.80 cm). Likewise, Gautam was tallest (86.56 cm) and 35th ESWYT112 had shortest plant height (68.76 cm) under late sown condition.

Similarly, the mean number of grains per spike for normal sown condition was 44 (Table 4). The highest number of grains per spike was recorded successively on 35th ESWYT112 (56),

35th ESWYT109 (51.06) and 35th ESWYT119 (50.46) in normal sowing. Meanwhile under late sowing, the average number of grains per spike was 38 with the highest observed on 35th ESWYT114 (46.33) and lowest on 5th HPYT403 (28.40).

The mean TKW was 38.64 g in normal sowing and 31.05 g in late sowing (Table 4). There was 19.64% reduction in TKW in late sowing. In normal sown condition, TKW varied from 26.70-48.86 g. The highest TKW was recorded on 35th ESWYT129 (48.86 g) followed by Gautam (47.66 g), Vijay (45.42 g) and 35th ESWYT114 (45.31 g) whereas lowest was recorded on 35th ESWYT112 (26.70 g) followed by 35th ESWYT105 (28.17 g) and 35th ESWYT106 (28.68 g). Similarly in late sowing, TKW was in the range of 24.86-42.04 g with highest on Vijay (42.04 g) and Gautam (41.20 g) and lowest on 35th ESWYT147 (24.86 g) and 35th ESWYT141 (25.40 g), respectively.

DISCUSSION

The study was aimed at evaluating elite spring wheat lines under normal and late sown conditions, in terms of agronomic performance and grain yield and variability of heat and drought adaptive physiological traits, early vigor and root characteristics. Significant genotypic differences were observed for all agro-morphological traits which are in agreement with the findings by Singh *et al.*[3], Hobbs *et al.*[5], Bered *et al.*[7] and Ali *et al.*[8]. Root count and root length significantly varied for two sowing dates. Similar findings for root traits under stress condition were reported by Ozturk *et al.*[9] and Mujtaba *et al.*[10]. Nayeem and Deshpande[11] recommended selection for seed index and seedling fresh weight and root length for the improvement of dry matter production in wheat. The present context of study of seedling and root features as related to crop performance can be helpful to identify proxy traits for enhancing adaptation to different soil properties, such as moisture and nutrient availability, soil compactness and abiotic and temperature stress, investigated by Bacon *et al.*[12], Hochholdinger and Tuberosa[13], Tuberosa[14] and Lynch[15]. Wheat grown under late sown conditions is exposed to low temperature up to booting stage, but the later stages face higher temperature that inhibits grain development, resulting into poor grain yield[3]. The detrimental effect of delayed sowing on grain yield of wheat crop was maximum with reduction in thousand grain weight according to Singh and Pal[16], Subhan and Khan[17] and Ojha[18]. In the late planting season, soil temperature can be expected to be below 10°C, which affects seedling emergence, root's growth and architecture and stand establishment, ultimately producing less number of effective tillers and finally decreasing grain yield.

CONCLUSION AND RECOMMENDATION

On the basis of results obtained from the present study, it can be concluded that almost all of the traits manifested superiorly on normal date of sowing. Significant genotypic differences for root count and root length under late sowing indicate that genotypes exhibit significant difference at seedling stage when some stress conditions are provided rather than growing under normal condition. The 35th ESWYT114, 35th ESWYT138, 35th ESWYT119, 35th ESWYT129, 5th HPYT402 and 5th HPYT438 including checks; Vijay and Gautam showed better and stable performance for most of the root, early vigor and grain yield traits under both sowing dates. So, the biological and economic yield of wheat can be increased through the proper root growth and development at seedling stage and reduction of heat stress at later growth stages by optimum time of planting. Therefore, identifying and developing the deeper rooting and heat stress tolerant genotypes should be prioritized in future breeding programs for successful wheat production.

SIGNIFICANCE STATEMENTS

This study discovers the importance of planting time in the growth and morphology of wheat crop and the effect of stress condition on root traits, how the wheat genotypes vary for root traits when they are grown in moisture stress rather than growing in normal condition that can be beneficial for researchers in future wheat breeding programs for heat stress and drought tolerance. So, this study will help the researchers to uncover the critical areas of wheat seedling growth and root traits which are pivotal for better agronomic performance (in terms of growth and yield in later stages of crop) in moisture stress environment.

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