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Screening wheat genotypes for coleoptile length: A trait for drought tolerance

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Abstract: The study was conducted during Rabi season of 2013-14 at the Wheat Research Centre (WRC), Bangladesh Agricultural Research Institute (BARI), Dinajpur. Thirty wheat genotypes including local control BARI Gom 26 were evaluated in split-split plot design having two replications with irrigation in the main plot, seeding depth in a sub-plot and genotype was in sub-sub-plot. The main objective of this study was to evaluate new exotic lines against drought, with emphasis on coleoptile length under Bangladeshi conditions, and to identify drought tolerant germplasm. To measure potential coleoptile length (CL), disease free, healthy, uniform seeds were sown in wooden trays with sandy soil in a temperature controlled room at 200 degree days (20^{o} c X 10 days). The genotypes were evaluated for yield, and yield components i.e., plant establishment, plant height (cm), spikes per m^2, grains per Spike, 1000-grain weight (g) and visual grain quality. Selection of genotypes was based on Schneider's stress severity index (SSSI), yield under drought condition and coleoptiles length. Deep seeding over normal seeding had a significant effect on yield and the yield components, as did water stress. The interaction of the two factors showed that seeding depth causes more yield loss than irrigation. More traits showed significant relationships in deep seeding conditions than normal conditions, meaning that there is greater scope for screening wheat using sowing depth. Based on higher negative value of SSSI and higher yield in deep sowing conditions the genotypes G 16, G 13, G 12, G 24, G 2, G 18, G 19 and G 3 were primarily selected for drought tolerance and will be evaluated further for advanced studies. These genotypes also have longer coleoptiles ranging from 7.4 to 10.5 cm.

Keywords: Wheat, Drought Tolerance, Deep Sowing, Coleoptile Length, Irrigation, Index

1. Introduction

Climate change in Bangladesh is expected to aggravate the situation along with the withdrawal of upstream water, resulting in increasing droughts and depletion of the water table. Crop production becomes impossible especially in drier northern and western regions of the country. Bangladesh already faces drought in the northwestern region [10] and it is expected that the moderately drought affected areas will become severely drought prone areas within the next two decades. The intensity and frequency of climatic hazards has brought to light the necessity for introducing stress tolerant varieties into breeding programs in Bangladesh, and for quick extension to growers. In addition, global climate change is negatively affecting crop yields under the current climate and is predicted to have a more severe impact on food production in future climate scenarios [22].

Wheat (*Triticum aestivum* L) is the second most important cereal crop in Bangladesh in respect of area and production cultivated in the winter season. However, due to light rainfall and scarcity of available irrigation facilities in the winter season, it suffers from soil moisture stress during the growing period. Being adapted to a wide range of moisture conditions, wheat is grown on more land area worldwide than any other crop, including in drought prone areas. In these marginal rain-fed environments where at least 60 m ha of wheat is grown, amount and distribution of rainfall are the predominant factors influencing yield variability [35]. Exposure of plants to drought led to a noticeable reduction in yield and yield contributing characters such as plant height, number of spikes per plant, total dry matter, number of seeds per spike, and 100- grain weight and grain yield [20]. There is an ever increasing interest in improving drought tolerance of wheat to attain a yield substantial enough to meet the increasing demand of a rapidly increasing population through breeding for drought tolerant and high yielding cultivars [54].

1.1. Significance of Long Coleoptile

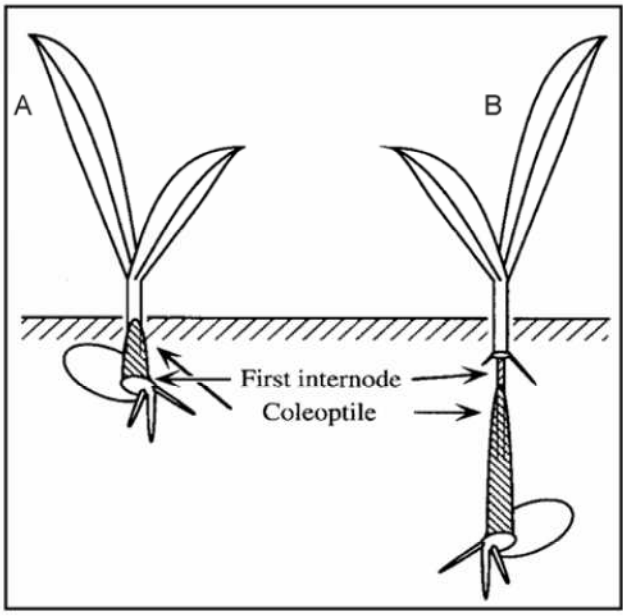

Fig 1. Schematic presentation of seedling growth under normal (A) and deep-seeding (B) conditions.

The coleoptile is an outer covering that protects the first leaf of the developing wheat plant as it pushes its way toward the surface of the soil during germination. If the coleoptile is shorter than the sowing depth, the first leaf must push through the soil and emerge in a dark environment. The longer it takes the first leaf to reach the surface, the more vulnerable the seedling is to soil crusting and diseases [21]. The coleoptile is essential for successful emergence and early plant vigour. Drought could promote the increase of Coleoptile Length (CL) and inhibit seedling height [21].

Wheat with long coleoptiles emerges with higher frequency than those with short coleoptiles especially when sown deep. [45, 46 and 47] When sown deep, wheat seedlings with short coleoptiles do emerge but much later and lack seedling vigour [19 and 47]. Deep sowing allows growers to exploit soil moisture lying below the drying topsoil and is an option considered by growers in Australia [11]. In some genotypes, shoots are able to reach the soil surface from the deep soil by elongating basal organs, e.g. coleoptile and first internode in wheat and barley [64] (Figure 1). Deeper sowing also assists in reducing removal of seeds by birds and rodents [8] and in avoiding phytotoxicity associated with some pre-emergent herbicides [40]. Deep sown seedlings with short coleoptile have smaller relative growth rates and slower leaf area development resulting in smaller leaf area early in the season which reduces the competitiveness of wheat crop against weeds and increases water loss through evaporation from the soil surface thus reducing crop water use efficiency, biomass and finally yield [30]. Deep seed placement and reduced coleoptile elongation in the predominantly hot soil can have a potentially devastating impact on stand establishment [55]. It was reported that seed size had little impact on coleoptiles lengths in barley but not in wheat and oats [9]. Studies have demonstrated a strong association between coleoptiles length and seedling emergence with shallow [14] and deep sowing [19, 29, 32, 50 and 61]. Surveys of Australian farmers' fields show that grain yield is reduced by a minimum 10% when short coleoptiles wheats are sown deeper than 5 cm [49]. Reduced establishment and lower grain yields associated with deep sowing have been reported for shorter coleoptile wheats [31, 32, 37, 44 and 50]. A recombinant inbred line (RIL) population showed considerable variation, normal distribution and transgressive segregation for CL under field and controlled environment conditions [26].

Wheat with longer coleoptiles emerged sooner, produced more plants and had greater early vigour particularly with deep sowing. Semi dwarf wheat has CL 30–40% shorter than non-semi dwarf wheat [2]. Selection for CL usually occurs in either a greenhouse in controlled environment condition or in field plots through deep planting. Selection under the controlled conditions of a growth chamber has the advantage of being quicker, cheaper and possibly more effective for increasing CL than field selection [25]. Selection of wheat cultivars with long coleoptile is an important component of improving emergence, weed suppression and grain yield in low rainfall regions. This would be useful tool in managing climate variability and would assist wheat growers to sow closer to the optimum sowing time in situations where moisture is present at depth but not on the soil surface. Considerable genetic variation has been observed for this trait and several studies have reported relationship between CL and seedling emergence and subsequent effect on early growth, biomass and grain yield.

2. Materials and Methods

The experimental material of the study was consisted of thirty genotypes of spring wheat (*Triticum aestivum* L.) including local control variety BARI Gom 26, collected from "4th CSISA drought yield trial 2011-12" [63]. To measure potential CL of the materials, disease free, healthy uniform seeds were sown in wooden trays with sandy soil in a temperature controlled room at 200 degree days (20^o c X 10 days). The field study was conducted at the experimental field of the Wheat Research Centre (WRC), Bangladesh Agricultural Research Institute (BARI), Dinajpur during 2013-14 cropping season. The genotypes were grown in rain fed, irrigated, deep seeding (around 5 cm below the soil surface) and normal seeding conditions (around 10 cm below the soil surface). Three irrigations were applied in the irrigated plots whereas no irrigation was applied in non irrigated plots to induce water stress. Root depths were between 5 cm below soil surface and around 10 cm below soil surface. The experiment was laid out in split-split plot design with two replications with irrigation in the main plot, seeding depth in the sub-plot and genotype in the sub-sub-plot. Randomization for the trial was generated by Cropstat 7.2 software [23]. Seeds were sown continuously in 2.5m long, 4-row plots with a row spacing of 20 cm with 1 meter between replicates. A two meter distance was maintained between the irrigated and non irrigated plots to control the unexpected water movement from irrigated plots to non irrigated plots. Recommended fertilizers and cultivation practices were followed in every plot. Data were recorded on yield (Y) and other yield contributing characters e.g., plant establishment (EPP), plant height in cm (PH), number of spikes per m^2 (SPN), grains per Spike (GPS) and 1000-grain weight in grams (TGW). At maturity, the whole plot was harvested to estimate grain yield measured in kg per hectare. Data were analyzed by ANOVA using Cropstat 7.2 software. A correlation matrix was calculated by Mltibase_2015 add-in to MS Excel [36]. Duncan's multiple range test was performed by using DSAASTAT add-in to MS Excel [41].

Selection of genotypes was based on index proposed by a modified formula of Stress Susceptibility Index (SSI) [15]. According to the formula (Yi)s denote the yield of the ith genotype under stress, (Yi)ns the yield of the ith genotype under nonstress (i.e., irrigated) conditions and Ys and Yns is the mean yields of all genotypes evaluated under stress and nonstress conditions, respectively. SSI is expressed by $SSI = \frac{1-\frac{(Yi)s}{(Yi)ns}}{SI}$, SI, the stress intensity is estimated as$SI = 1 - \frac{Ys}{Yns}$. Lower SSI values indicate lower differences in yield across stress levels, in other words, more resistance to drought. The modified formula for Schneider’s stress severity index [51, 52] is $SSSI = (1 - \frac{(Yi)s}{(Yi)ns}) - \left(1 - \frac{Ys}{Yns}\right)$. The SSSI estimates the relative tolerance for yield reduction of a genotype relative to the population mean reduction in grain yield response due to stress. Selections based on these indices were carried out by many authors [18, 28, 39, 42, 43, 52, 53, and 57].

3. Results and Discussion

The average coleoptiles lengths of the 30 genotypes varied in range, presented in table 1. The CL varied from 3.5 cm (G6) to 12.10 cm (G12) in different genotypes and the highest mean CL was 10.9 cm in G 25. The mean CL was recorded above 10 cm in G26, G30, G12 and G20, and 5 genotypes (G22, G 11, G 17, G 24 and G 21) were produced from 9.0 to 9.9 cm. Mean CL from 8.2 cm to 8.8 cm was in 8 genotypes. Another group having 7 to 7.8 cm CL consist of 8 genotypes. The remaining 4 genotypes vary for mean CL between 5.5 and 6.8 cm. CL variation among the CIMMYT lines in this collection was very narrow with the majority having a CL between 7-10.9cm. This narrow variation is probably due to the semi-dwarf nature of all the collected lines and/or due to a common genetic background and having been previously selected from 4th CSISA drought trial. A number of non-genetic factors have been reported to affect seedling vigour and CL including variation in grain size [27, 13], grain positions in the ear [56] and the environment from which the grain was harvested [37, 44]. Seed source is obviously a very important determinant of CL [24].

Table 1. *Average CL with range of 30 genotypes.*

Genotype	Average CL (cm)	Range (cm)	Genotype	Average CL (cm)	Range (cm)	Genotype	Average CL (cm)	Range (cm)
G-1	7.5	5.5-9.5	G-11	9.8	8.8-10.2	G-21	9.3	6.7-10.8
G-2	8.2	6.1-11.0	G-12	10.5	6.2-12.1	G-22	9.9	7.2-11.5
G-3	7.5	5.0-10.5	G-13	7.4	5.2-11.5	G-23	6.1	4.9-8.1
G-4	7.6	7.1-7.9	G-14	7.7	5.9-9.5	G-24	9.5	8.0-10.9
G-5	7.8	5.8-9.6	G-15	8.5	7.0-10.5	G-25	10.9	9.0-11.9
G-6	5.5	3.5-9.5	G-16	8.7	6.9-11.5	G-26	10.8	10.1-11.3
G-7	8.5	5.0-11.4	G-17	9.8	8.5-11.0	G-27	7.3	5.9-10.1
G-8	8.8	6.6-12.0	G-18	8.7	7.5-10.6	G-28	6.8	5.2-9.3
G-9	6.8	5.4-9.0	G-19	8.6	6.2-10.8	G-29	7.0	5.0-9.0
G-10	8.6	7.0-10.8	G-20	10.2	8.3-11.6	G-30	10.8	9.0-11.6

Table 2. *Analysis of variance and coefficient of variation (CV) of each trait with different treatments in the field condition.*

Variation Source	df	Mean sum of squares					
		EPP	PH	SPN	GPS	TGW	Y
Sowing depth (D)	1	111208**	817.705**	656993**	5219.2**	136.33**	77535400**
Irrigation (IR)	1	291.233	24.7042	187042**	448.814**	3.37542	100255000**
D X IR	1	304.601	30.1041	8449.07*	52.8282	13.1552	1368520
Genotype (G)	29	337.558**	41.6323	4080.67**	83.695**	26.6389**	2345680**
IR X G	29	121.021	44.1956	5408.37**.	43.8669	12.3041	951139**
D X G	29	460.024**	53.6955	5599.47**	66.3746**	9.84239	1724130**
D X IR X G	29	135.765	31.7507	3498.87**	39.1607	11.7532	831609*
CV		18.5	7.5	14.9	10.4	9.1	14.5

The mean sums of squares for the characters studied are presented in table 2. The mean sums of squares due to genotypes were significant for five characters studied while PH shows no significance for genotypes. The mean sum of squares suggests that the genotypes selected were genetically variable and a considerable amount of variability existed among them. This indicates selection for different quantitative characters for wheat improvement. These findings are in accordance with the findings of [3, 6 and 12] who also observed significant variability in wheat germplasm. Analysis of variance also revealed significant differences between treatments and among the genotypes. All the traits studied varied significantly for sowing depth while only SPN, GPS and Y showed a significant variation for irrigation. The sowing depth × genotype interactions were also significant for all the characters except PH and TGW. On the other hand Irrigation X Genotype interaction is significant for SPN and Y. This interaction revealed that genotypes performed inconsistently over the stress conditions. This significant variation in water stress conditions may serve as good indicator of drought tolerance.

The correlation coefficients of yield and yield contributing characters indicated some significant relation exist among the character studied. More traits showed significant relationship in deep seeding condition than normal condition, meaning that there is greater scope for screening wheat using sowing depth. CL showed a non-significant relationship except with number of spikes in irrigated deep seeding condition. As in [4 and 16] we found that plant height and CL were not significantly correlated. There were no differences in the mean plant height for entries with coleoptiles longer than 90 mm in wheat as in [34]. They also indicated that coleoptiles longer than 90 mm showed no advantage for emergence from deep planting and might even have a negative effect. Again, it was also found that thousand kernel weight did not affect emergence on any days after planting nor was it associated with plant height at maturity [34]. It was revealed that wheat seedling emergence did not have linear relationship with CL as many other factors have been implicated in the process [48, 7 and 38]. Emergence and CL is reported to be influenced both by genetic background and environmental factors including soil texture, seed-zone water content, temperature, light penetration, and crop residue [58]. As we do not know the nature of dwarfing genes in the world collection, these could possibly be gibberellic acid (GA) sensitive genotypes that are reported to have no adverse effect on CL but reduce plant height, or possibly have favorable alleles for CL in semi-dwarf background [60].

Table 3. *Simple Correlation coefficient between yield and the traits associated with yield.*

Table 3a. *Correlation Coefficient Matrix for normal sowing in irrigated and non-irrigated condition*

	CL	EPP	PH	SPN	G	TGW	Y
CL		0.18	-0.04	0.30	-0.07	-0.01	-0.08
EPP	0.01		0.34	0.31	-0.25	-0.23	0.43*
PH	-0.09	0.23		0.17	0.15	-0.23	0.20
SPN	-0.28	0.09	0.28		-0.41*	-0.23	0.15
GPS	0.12	-0.34	0.02	0.12		0.14	0.02
TGW	0.15	-0.24	-0.26	-0.25	0.10		0.04
Y	0.22	-0.08	0.19	0.16	0.25	-0.06	

Parentheses are the r^2 of non-irrigated condition

Table 3b. *Correlation Coefficient Matrix for deep sowing in irrigated and non-irrigated condition*

	CL	EPP	PH	SPN	GPS	TGW	Y
CL		-0.09	0.25	0.43*	-0.18	-0.01	-0.05
EPP	-0.11		0.21	0.23	-0.24	-0.10	0.45**
PH	-0.30	0.28		0.47**	0.09	-0.08	0.55**
SPN	-0.19	0.26	0.57**		-0.09	-0.09	0.68**
GPS	-0.06	-0.32	-0.46**	-0.32		-0.36*	0.25
TGW	-0.27	-0.04	0.23	0.21	-0.36*		-0.14
Y	-0.15	0.32	0.36*	0.58**	-0.12	-0.10	

Parentheses are the r^2 of non-irrigated condition

Table 4. *Mean effect of depth of seeding on yield and yield contributing characters of wheat.*

Treatment	EPP	PH	SPN	GPS	TGW	Y
Normal Seeding	78	97.4	328	49	46.11	5359
Deep Seeding	33	93.4	223	59	44.70	4151
F- value	**	**	**	**	**	**
LSD (5%)	2.63	1.82	10.49	1.43	1.05	176.39
CV	14.7	7.6	16.3	10.2	9.2	13.3

Table 4 shows that seeding depth had a significant effect on yield and yield components in wheat. Higher seedling emergence, taller plant, more spikes per square meter, increased thousand grain weight and ultimately higher grain yield was found in normal seeding condition compared to deep seeding condition. Fewer grains per spike were observed in normal seeding condition than deep seeding. As in [1] semi dwarf varieties of wheat produced more grains per spike when planted at 10 cm deep where moisture was not a limiting factor. An increased number of grains per spike as well as grain yield per spike was noted in a local wheat variety had sown under 9 cm deep below the soil surface [33].

Table 5. *Mean effect of water stress on yield and different yield parameters of wheat*

Treatment	EPP	PH	SPN	GPS	TGW	Y
Irrigated	55	95.7	303	56	46	5419
Water stressed	57	95.1	247	53	45	4091
F- value	ns	ns	**	**	ns	**
LSD (5%)	2.63	1.82	10.49	1.43	1.05	176.39
CV	14.7	7.6	16.3	10.2	9.2	13.3

Table 6. *Interaction effect of yield and yield parameters imposed by depth and irrigation.*

Treatment		EPP	PH	SPN	GPS	TGW	Y
Normal Seeding	Irrigated	78	97.2	349	50	46.5	5960
	Water stressed	78	97.6	306	48	45.7	4758
Deep Seeding	Irrigated	31	94.2	257	61	44.7	4878
	Water stressed	36	92.6	189	57	44.7	3424
F- value		**	ns	**	**	ns	**
LSD (5%)		3.73	2.58	14.83	2.03	1.49	259.46
CV		14.7	7.6	16.3	10.2	9.2	13.3

Table 7. *Yield of wheat genotypes in different treatments and Schneider's stress severity index (SSSI) with average CL.*

Genotype	Yield (Kg/h)*								SSSI		CL
	Normal Seeding				Deep Seeding				Normal seeding	Deep Seeding	
	Irrigated		Dryland		Irrigated		Dryland				
G 1(BARI Gom 26)	5080	bc	4700	abc	3960	efghi	4770	abc	-0.125	-0.505	7.5
G 2	5710	abc	5535	ab	5084	abcdef	4114	abcdef	-0.169	-0.109	8.2
G 3	6547	ab	4050	bc	4326	defgh	3140	cdefghij	0.181	-0.026	7.5
G 4	7355	a	5305	ab	3391	ghi	2266	ij	0.079	0.032	7.6
G 5	5965	abc	3870	bc	3324	hi	2825	efghij	0.151	-0.150	7.8
G 6	6280	abc	3059	c	3380	ghi	2010	j	0.313	0.105	5.5
G 7	5310	bc	5000	ab	2290	i	2416	fghij	-0.142	-0.355	8.5
G 8	6105	abc	4280	bc	5860	abcd	3705	abcdefghij	0.099	0.068	8.8
G 9	5640	abc	4880	ab	3165	hi	2425	fghij	-0.065	-0.066	6.8
G 10	6085	abc	5000	ab	3805	fghi	2695	fghij	-0.022	-0.008	8.6
G 11	6390	abc	4135	bc	4505	cdefgh	2285	hij	0.153	0.193	9.8
G 12	6760	ab	4225	bc	4330	defgh	3630	abcdefghij	0.175	-0.138	10.5
G 13	6050	abc	4810	ab	5505	abcde	4885	ab	0.005	-0.187	7.4
G 14	5960	abc	5095	ab	6580	a	4505	abcde	-0.055	0.015	7.7
G 15	6245	abc	5240	ab	5215	abcdef	3295	bcdefghij	-0.039	0.068	8.5
G 16	5965	abc	4640	abc	5650	abcd	5295	a	0.022	-0.237	8.7
G 17	6485	ab	5150	ab	5400	abcdef	2690	fghij	0.006	0.202	9.8
G 18	6105	abc	4360	bc	5035	abcdefg	3920	abcdefghi	0.086	-0.079	8.7
G 19	5860	abc	4435	abc	5950	abcd	4535	abcd	0.043	-0.062	8.6
G 20	5315	bc	4910	ab	3890	efghi	2330	hij	-0.124	0.101	10.2
G 21	6585	ab	5125	ab	5875	abcd	2935	defghij	0.022	0.200	9.3
G 22	5345	bc	5395	ab	5850	abcd	3860	abcdefghi	-0.209	0.040	9.9
G 23	5875	abc	5380	ab	6450	ab	2990	defghij	-0.116	0.236	6.1
G 24	5940	abc	4580	abc	5950	abcd	4865	ab	0.029	-0.118	9.5
G 25	4655	c	3925	bc	3850	efghi	2645	fghij	-0.043	0.013	10.9
G 26	5195	bc	6140	a	5045	abcdefg	3400	bcdefghij	-0.382	0.026	10.8
G 27	5555	bc	4060	bc	5805	abcd	3855	abcdefghi	0.069	0.036	7.3
G 28	6695	ab	5045	ab	6210	abc	4065	abcdefg	0.046	0.045	6.8
G 29	5920	abc	5115	ab	5905	abcd	4005	abcdefgh	-0.064	0.022	7
G 30	5835	abc	5290	ab	4755	bcdefgh	2365	ghij	-0.107	0.203	10.8
Mean	5960		4758		4878		3424				

*Duncan's multiple range test (p= 0.05)

Plant establishment was counted before CRI stage when no irrigation was applied, thus table 5 revealed no variation in plant establishment in both irrigated and non-irrigated plots. Irrigation had also no effect on plant height. These non-significant variations might be due to the semi-dwarf stature of the genotypes having very little or no variation for plant height. As we do not know the nature of dwarfing genes in the genotype collection, these could possibly be GA sensitive genotypes that are reported to have no adverse effect of irrigation but reduce plant height, or possibly have favorable alleles for drought effect in a semi-dwarf background [60]. Spikes per square meter, grains per spike, thousand grain weight and yield varied due to irrigation in wheat. Similar results were recorded as in [58] where a significant effect of irrigation on 1000-grain weight was reported. Application of five irrigations at different wheat growth stages resulted in higher spike length, higher number of grains and wheat grain yield [5].

Mean interaction effect of seeding depth and irrigation in table 6 revealed that highest yield was obtained from irrigated normal seeding condition whereas lowest yield was from the non-irrigated deep sowing condition. No significant difference in yield was observed between non irrigated deep seeding conditions and irrigated normal seeding conditions. Spikes per square meter and number of grains per spike were highest (mean) in irrigated deep seeding condition. As several authors indicate that CL has a significant effect on yield and yield controlling characters, and a negative but non-significant correlation of CL found in this experiment (table 3), screening of wheat genotypes for drought and CL through deep planting might be fruitful.

G 4 was the highest yielder (7355 kg) followed by G 12, G 28, G 21 and G 3, respectively whereas genotype 25 (4655 kg) was the lowest yielder in irrigated normal seeding condition (table 7). G 26 (6140 kg) was the maximum yielder followed by G 2, G 22, G 23 and G 4 in normal seeding in the dryland condition, whereas G 6 (3059 kg) was the lowest yielder for this environment. The highest yield under deep sowing with regular irrigation was found in G 14 (6580 kg) followed by G 23, G 28, G24 and G 19 respectively and the lowest yielder was G 7 in this condition.. Moreover, the table revealed that G 16 (5295 kg) was the maximum yielder in the non-irrigated deep sowing condition followed by G 13, G 24 and G 19. Yield was lowest in G 6 (2010 kg) in non irrigated deep sowing condition.

Sixteen genotypes showed positive SSSI values for normal seeding condition, suggesting that they suffered high stress and high grain yield loss for irrigation in normal seeding. Fourteen genotypes had negative SSSI values, indicating that they experienced low stress and low grain yield loss in the same condition. Similarly, positive SSSI values for 17 genotypes in deep seeding condition indicated that they are prone to stress caused by drought induction, and also suffered greater grain yield loss. Negative SSSI values for 13 genotypes in the deep seeding condition indicate that they experience low stress in drought conditions caused by no irrigation in deep sowing.

No irrigation in the deep sowing condition imposed drought and allowed the genotype to survive in a deeper layer of soil by absorbing deep soil moisture. The survival within a deeper layer of soil must have some genotypic basis for drought tolerance. This stress tolerance is also related to coleoptiles length [11, 19, 29, 32, 37, 45, 46, 47, 48, 61 and 62]. Based on the higher negative value of SSSI and higher yield in deep sowing conditions the genotypes G 16, G 13, G 12, G 24, G 2, G 18, G 19 and G 3 were primarily selected for drought tolerance and will be evaluated further for advanced studies. These genotypes also have longer coleoptiles ranged from 7.4 to 10.5 cm.

4. Conclusion

Considering the overall yield and other characteristics, eight genotypes have been provisionally selected at WRC, Dinajpur for further evaluation for drought tolerance and can be included in crossing blocks. The variability for CL may be partly accounted for by the unexplained variation in the relationship between CL and sowing depth. High gain from selection for increased CL requires that screening conditions are repeatable and that phenotypic differences in CL largely reflect underlying genetic factors. Large variability in seed depth arising from non uniform seed placement demonstrates the need for better sowing equipment if screening directly for CL in the field. Further testing is required to adapt the method for a wider range of crop types and soil conditions and testing for crops grown to maturity.

Authors' Contributions

Md. Farhad was the principle investigator (PI) who planed and set-up the experiment. Md. Abdul Hakim and Dr. Md. Ashraful Alam helped the PI to collect data, analysis the data and manuscript preparation. Dr. N. C. D. Barma had technical contribution by suggesting the plan of experiment and data collection and interpretation.

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