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ROOT GROWTH CHARACTERISTICS AND PRODUCTIVITY OF SOME CHICKPEA GENOTYPES UNDER IRRIGATED AND NON-IRRIGATED CONDITIONS

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ABSTRACT

Eight chickpea genotypes were grown in the field condition with and without supplemental irrigation. Both root length and weight densities of these genotypes were affected by moisture stress. The genotypes ICCV-92065, ICCV-94912 exhibited lower yield under moisture stress situation. BARI chola-4, ICCV-94923, and Annigiri maintained better root length under moisture stress situation of which BARI chola-4 was the most promising genotype in terms of yield and harvest index, and BARI chola-6, ICCV 92501 and ICCV-94923 were closely following it.

Keywords: Chickpea, root length density, root weight density.

INTRODUCTION

The importance of root traits in adaptation to drought environments is well recognized. Root growth and its expression are markedly affected by environmental factors (Hamblin and Hamblin, 1985), particularly under moisture stress (Klepper, 1988). Among the root characteristics both length and density are important, since root length is directly related to the quantity of water extracted (Mayaki *et al.*, 1976). Pandey *et al.* (1984) also reported that shoot dry weight was less reduced in legumes, which exhibited greater root length density at deeper soil depth. Increase in Root Weight Density (RWD) under moisture stress condition was in accordance with Rowse (1974) who showed that non-irrigated plants had thicker roots and greater length and weights in the deeper soil layers. But Gregory (1976) emphasized on the total root length and the relative distribution within the soil profiles to be affected by moisture. Large build-up of root mass (weight) in some genotypes seemed to be associated to poorer pod development, which ultimately resulted poor seed yield, and lower harvest index (Saxena *et al.*, 1990). So, it might be reasonably argued that root weight did not always play significant role in yield performance in terms of yield stability or higher yield, although it might have influence on drought tolerance or avoidance. Although the exact relationship between increased root mass and loss in shoot mass, particularly yield components and harvest index was not possible to establish, it might be assumed that unusual increase in root weigh despite decrease in root length might had probably led to favourable dry matter partitioning towards root systems and also resulted reduced water and nutrient uptake by the root systems of the chickpea genotypes, which ultimately affected the yield components. Both root length, weight, and its distribution seemed to be important for drought avoidance and lower yield reduction under drought stress. In the light of these circumstances the study was undertaken to evaluate the root growth characteristics as well as to compare the yield performance of chickpea genotype(s).

Genotypes which retain high leaf water content (RLWC) during drought stress were considered by Good and Maclayan (1993) as drought tolerant, although Flower and Ludlow (1986) mentioned that low lethal water status influences survival having no direct effect on yield components. Gregory (1988) underlined the importance not only of the ratio of root to shoot weight, but also moisture and its import to the shoot, since the effect of moisture stress might exert influence on the attainment of biomass followed by a high partitioning to seed as a major requirement of high seed yield (Silim *et al.*, 1985).

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Pandey *et al.* (1984) also emphasised that shoot dry weight was less reduced in legumes, which exhibited greater RLD at deeper soil depths, although they did not report on the impact of RWD on these parameters. In the light of these circumstances the study was undertaken to evaluate the root growth characteristics as well as to compare the yield performance of chickpea genotype(s).

MATERIALS AND METHODS

The experiment was conducted on upland plot at the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. The soil was silty-clay loam soil with pH 6.7. Bulk densities at 0-10 cm, 10-20 cm and 20-30 cm soil depths were 1.243, 1.491 and 1.473 g cm^{-3} respectively. The experiment was laid out in Factorial Randomized Complete Block Design with three replications. Two levels of irrigation viz irrigated (I_I) and non-irrigated (Io) were applied on eight chickpea genotypes viz. Annigiri, BARI chola-4, BARI chola-6, ICCV 92501, ICCV 92065, ICCV 94912, ICCV 94918 and ICCV 94923. An isolation distance of 1.1 m between two unit plots and 3m between two replications was maintained to avoid unexpected seepage or run off of irrigation water into adjacent non-irrigated plots. Light sprinkler irrigation was applied to all the plots to ensure uniform seed germination. After seed germination, only control plots were irrigated at 40 and 55 DAE, which include flowering and pod filling stage. Applying no irrigation at any growth stages imposed moisture stress. The roots of chickpea were collected using Core Sampler (50.24 cm inter diameter and 10 cm height) and total root length (RL) was computed using the method described by Newman (1966) and oven dry weights of the roots (RW) were taken to determine Root Length Density (mm cm^{-3}) = RL / SV (mm cm^{-3}) and Root Weight Density ($\mu g\ cm^{-3}$) = RW / SV ($\mu g\ cm^{-3}$), where SV = Volume of the soil sample (cm^3) = $\pi r^2 h$, r = Radius of the core sampler (cm), h = Height of the core sampler (cm). Relative leaf water content (RLWC) was measured using the formula of Turner (1981): RLWC = (Fw – Dw) / (Tw-Dw) x 100, where, Fw = Fresh leaf weight (g), Dw = oven dry leaf weight (g), Tw = Turgid leaf weight (g). Oven dried shoot of individual plant was measured with a digital electronic balance. Yield and yield contributing characters of 10 plants of samples from each treatment were harvested separately. Grain yield of 3 m^2 harvested area marked earlier each plot was taken and converted to kg/ha. Percent change for several parameters were measured as $I_I - I_0 / I_I \times 100$, where I_I = Parameter under irrigated condition and I_0 = Parameter under non-irrigated condition.

RESULTS AND DISCUSSION

Root length density (RDL)
Moisture stress at flowering stage caused wide variations in RLD in different genotypes at different soil profile. The RLD decreased with increasing soil depth (Table 1).Within 0-30 cm soil depth, all the genotypes except BARI chola-6 suffered considerable losses in RLD under non-irrigated condition compared to irrigated treatment. But at pod filling stage, the highest average RLD was in ICCV 94912 and the lowest in Annigiri. Under non-irrigated condition, the highest average RLD was noticed in BARI chola-6 and the lowest in ICCV 94912. Annigiri in particular, showed a considerable gain in RLD at all the soil profile, while ICCV 94918 lost at every soil profile under similar condition. The gain in RLD by the genotypes i.e. Annigiri and BARI Chola-6 under moisture stress condition might be a good indication of their ability to proliferate root system under drought stress (Raja and Bishnoi, 1990; Gregory, 1988).

Table 1. Root length density as affected by irrigated and non-irrigated treatments

Genotypes	Growing stages	Soil depth (cm)							
		0-10		10-20		20-30		0-30	
		I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Annigiri	Flowering	3.36	2.56	2.30	1.44	2.35	1.04	2.67	1.68
		(-23.88)		**(-37.26)**		**(-55.87)**		**(-37.08)**	
	Pod filling	1.73	1.89	1.07	2.05	0.53	1.94	1.11	1.96
		(+9.44)		**(+91.87)**		**(+266.04)**		**(+76.58)**	
BARI chola-4	Flowering	5.13	1.68	2.30	1.41	2.35	1.85	3.26	1.65
		(-67.25)		**(-38.70)**		**(-21.28)**		**(-49.39)**	
	Pod filling	1.37	1.99	2.86	1.96	1.25	1.32	1.83	1.76
		(+45.47)		**(-31.47)**		**(+5.60)**		**(-3.38)**	
BARI chola-6	Flowering	4.88	1.94	2.58	3.04	0.64	1.17	2.70	2.32
		(-60.16)		**(+17.83)**		**(+82.81)**		**(-24.07)**	
	Pod filling	2.68	2.65	2.68	2.81	0.46	1.91	1.94	2.46
		(-1.34)		**(+5.23)**		**(+314.57)**		**(+26.80)**	
ICCV-92501	Flowering	3.94	1.07	5.67	2.01	2.82	2.00	4.14	1.69
		(-72.79)		**(-64.46)**		**(-28.97)**		**(-59.18)**	
	Pod filling	4.57	2.01	2.46	2.47	1.12	0.92	2.72	1.8
		(-55.95)		**(+0.41)**		**(-17.64)**		**(-33.82)**	
ICCV-92065	Flowering	5.51	3.16	3.29	3.13	1.53	1.08	3.44	2.46
		(-42.60)		**(-4.87)**		**(-29.27)**		**(-28.49)**	
	Pod filling	4.00	1.75	1.24	1.50	2.59	1.19	2.61	1.48
		(-56.29)		**(+20.92)**		**(-53.88)**		**(-43.33)**	
ICCV-94912	Flowering	7.24	3.17	8.18	2.03	2.44	0.40	5.95	1.87
		(-56.24)		**(-75.22)**		**(-83.89)**		**(-68.57)**	
	Pod filling	5.32	1.81	4.72	1.03	1.33	1.05	3.79	1.30
		(-65.94)		**(-78.19)**		**(-21.05)**		**(-65.70)**	
ICCV-94918	Flowering	7.43	3.46	4.25	1.88	0.18	1.11	3.95	2.15
		(-53.41)		**(-55.87)**		**(+525.4)**		**(-45.57)**	
	Pod filling	3.22	1.92	2.27	1.73	1.32	1.72	2.27	1.79
		(-40.43)		**(-23.89)**		**(+30.08)**		**(-21.11)**	
ICCV-94923	Flowering	4.33	3.02	2.58	0.33	3.87	0.59	3.59	1.31
		(-30.32)		**(-87.21)**		**(-84.74)**		**(-63.51)**	
	Pod filling	2.97	2.36	1.81	0.63	0.69	1.32	1.82	1.44
		(-20.36)		**(-65.03)**		**(+91.70)**		**(-20.88)**	
CV (%)	Flowering	13.69		25.93		29.16		-	
	Pod filling	21.53		18.31		23.03		-	
LSD at α 0.05	Flowering	0.8850		0.9357		0.6997		-	
	Pod filling	0.9432		0.6396		0.5018		-	

** Value in the parentheses indicates percent decrease in root length density due to non-irrigated condition compared irrigated

** I_1 and I_0 denote irrigated and non-irrigated treatment respectively.

Root weight density (RWD)

At flowering stage all the genotypes showed a considerable decrease in RWD as the root system approached to deeper soil profiles. However, some genotypes exhibited considerable gain in RWD when put under moisture stress. Within 0-30 cm profile, the highest RWD was observed in ICCV 92501 and the lowest in Annigiri under irrigated treatment, while BARI chola 6 showed the highest and

BARI chola 4 showed the least RWD under non-irrigated condition. At pod filling stage, all the genotypes showed considerable decrease in RWD though Annigiri showed a considerable increase under non-irrigated condition (Table 2).

Table 2. Root weight density as affected by irrigated and non-irrigated treatments

Genotypes	Growing Stages	Soil depth (cm)							
		0-10		10-20		20-30		0-30	
		I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
Annigiri	Flowering	6.89	3.37	4.22	3.88	2.61	2.02	4.57	3.09
		(-51.09)		**(-7.89)**		**(-22.69)**		**(-32.39)**	
	Pod filling	8.78	7.58	2.52	4.89	2.19	4.55	4.50	5.67
		(-13.67)		**(+94.16)**		**(+107.48)**		**(+26.00)**	
BARI chola-4	Flowering	8.75	2.70	7.75	2.19	1.35	1.35	5.95	2.08
		(-69.19)		**(-71.74)**		**(0.00)**		**(-65.04)**	
	Pod filling	9.27	3.37	7.10	2.35	3.88	2.53	6.75	2.75
		(-63.53)		**(-66.90)**		**(-34.82)**		**(-59.26)**	
BARI chola-6	Flowering	9.10	7.58	4.89	10.28	1.69	1.69	5.23	6.52
		(-16.70)		**(+110.35)**		**(0.00)**		**(+24.67)**	
	Pod filling	11.80	7.42	4.38	7.72	0.84	2.88	5.67	6.01
		(-37.14)		**(+76.26)**		**(+241.99)**		**(+6.00)**	
ICCV-92501	Flowering	9.1	3.04	9.27	3.20	4.56	2.40	7.64	2.88
		(-66.63)		**(-65.48)**		**(-47.27)**		**(-62.30)**	
	Pod filling	7.75	7.42	5.05	3.54	2.02	1.18	4.94	4.05
		(-4.33)		**(-29.94)**		**(-41.52)**		**(-18.02)**	
ICCV-92065	Flowering	8.09	6.74	5.90	5.73	1.46	2.36	5.15	4.94
		(-16.71)		**(-2.83)**		**(+61.44)**		**(-4.08)**	
	Pod filling	13.13	1.85	4.55	2.36	5.39	3.20	7.69	2.47
		(-85.91)		**(-48.13)**		**(-40.66)**		**(-67.88)**	
ICCV-94912	Flowering	6.57	5.22	9.61	2.53	2.53	0.46	6.24	2.74
		(-19.99)		**(-93.70)**		**(-81.92)**		**(-56.09)**	
	Pod filling	6.74	5.09	9.27	4.22	4.38	6.74	6.80	5.35
		(-24.56)		**(-54.44)**		**(+53.95)**		**(-21.32)**	
ICCV-94918	Flowering	10.28	5.36	4.87	2.18	0.27	2.19	5.14	3.24
		(-47.86)		**(-55.26)**		**(+712.22)**		**(-36.96)**	
	Pod filling	7.59	3.20	5.39	3.71	1.06	1.86	4.68	2.92
		(-57.78)		**(-31.26)**		**(+74.69)**		**(-37.61)**	
ICCV-94923	Flowering	6.57	4.38	3.84	0.32	4.19	1.60	4.84	2.1
		(-33.33)		**(-91.67)**		**(-61.79)**		**(-56.88)**	
	Pod filling	6.61	6.24	9.10	2.02	2.70	5.39	6.14	4.55
		(-5.60)		**(-77.77)**		**(+99.99)**		**(-25.90)**	
CV (%)	Flowering	9.22		11.91		27.31		-	
	Pod filling	7.04		10.97		16.63			
LSD at α 0.05	Flowering	0.9993		0.990		0.9637		-	
	Pod filling	0.8594		0.8594		0.8818		-	

** Value in the parentheses indicates percent decrease in root weight density due to non-irrigated condition compared irrigated

** I_1 and I_0 denote irrigated and non-irrigated treatments, respectively.

Relative leaf water content (RLWC)

At flowering stage the highest RLWC was found in ICCV-94912 and the lowest in BARI chola-4. However, when the plants were subjected to moisture stress, different genotypes responded differently. BARI chola-6 lost the highest RLWC and the lowest was observed in ICCV-94923. At pod filling stage, the highest reduction in RLWC was observed in ICCV-94918 and the lowest was noticed in Annigiri (Table 3). Genotypes which retain high leaf water content (RLWC) during drought stress were considered by Good and Maclayan (1993) as drought tolerant, although Flower and Ludlow (1986) mentioned that low lethal water status influences survival having no direct effect on yield components.

Table 3: Relative leaf water content (RLWC) as affected by irrigated and non-irrigated treatments

Genotype	RLWC (%)			
	Flowering stage		Pod filling stage	
	I_1	I_0	I_1	I_0
Annigiri	71.744	63.173	75.963	72.105
	(-11.95)		**(-5.08)**	
BARI chola-4	65.381	59.539	69.476	64.891
	(-8.94)		**(-6.60)**	
BARI chola-6	76.802	60.547	80.288	70.196
	(-21.16)		**(-12.57)**	
ICCV 92501	74.554	66.508	76.101	70.78
	(-10.79)		**(-6.99)**	
ICCV 92065	76.009	66.794	84.001	75.402
	(-12.12)		**(-10.24)**	
ICCV 94912	81.188	64.388	78.217	73.786
	(-20.69)		**(-5.67)**	
ICCV 94918	74.841	68.62	74.811	64.673
	(-8.31)		**(-13.55)**	
ICCV 94923	75.296	69.614	78.941	69.259
	(-7.55)		**(-12.26)**	

** Value in the parentheses indicates percent decrease in RLWC due to non –irrigated condition compared irrigated
**I_1 and I_0 denote Irrigated and non-irrigated treatments respectively.

Shoot dry matter (SDM)

At flowering stage, the highest loss in SDM was observed in ICCV-92918 and ICCV-94923, while the lowest loss was observed in ICCV-92065. At pod filling stage, the highest loss in SDM was noticed in ICCV-92501 and the lowest was in ICCV-92065. ICCV 92065 incur less reduction in SDM at both flowering and pod filling stages under moisture deficit situation (Table 4).

Table 4: Shoot dry matter as affected by irrigated and non-irrigated treatments

Genotype	Shoot dry matter (g)			
	Flowering stage		Pod filling stage	
	I_1	I_0	I_1	I_0
Annigiri	11.45	7.65	17.59	15.03
	(-33.18)		**(-14.55)**	
BARI chola-4	8.24	6.34	13.85	12.37
	(-23.06)		**(-10.69)**	
BARI chola-6	7.34	5.57	17.62	13.08
	(-24.11)		**(-25.77)**	
ICCV 92501	7.60	5.94	19.14	12.37
	(-21.84)		**(-35.37)**	
ICCV 92065	8.88	7.48	15.48	13.91
	(-15.91)		**(-10.14)**	
ICCV 94912	9.50	7.48	15.74	13.90
	(-21.26)		**(-11.69)**	
ICCV 94918	7.48	4.79	17.50	11.87
	(-35.96)		**(-32.17)**	
ICCV 94923	10.79	7.91	19.37	15.88
	(-26.69)		**(-18.02)**	
CV (%)	7.7		5.67	
LSD at α 0.05	0.9937		0.9403	

** Value in the parentheses indicates percent decrease in shoot dry matter (SDM) due to non-irrigated condition compared irrigated
** I_1 and I_0 denote irrigated and non-irrigated treatments, respectively.

Gregory (1988) underlined the importance not only of the ratio of root to shoot weight, but also moisture and its import to the shoot, since effect of moisture stress might exert influence on the attainment of biomass followed by a high partitioning to seed as a major requirement of high seed yield (Silim *et al.*, 1985). Pandey *et al.* (1984) also emphasised that shoot dry weight was less reduced in legumes, which exhibited greater RLD at deeper soil depths, although he did not report on the impact of RWD on this parameters.

Yield and yield contributing characters

The highest seed yield was produced by ICCV-92065 under irrigated condition, which was attributed to its highest number of pods per plant, higher number of seeds per pod, and the highest seed yield per individual stand. However, under moisture stress situation all the yield contributing characters were affected considerably leading to a major reduction in total seed yield as well as harvest index. The lowest seed yield was produced by ICCV-94918 under non-irrigated condition, which was due to its lower number of pods per plant and lower number of seeds per plant. Although it produced heavier seeds, yet produced the lowest amount of seed per individual plant leading to lower harvest index. BARI chola-4, although yielded lower under irrigated condition, yet the reduction in yield and harvest index due to moisture stress was the lowest among the genotypes, which indicated its higher yield stability under moisture deficit condition.

Table-5. Yield and yield contributing characters of chickpea genotypes as affected by irrigated and non-irrigated treatments

Genotypes		Pods / plant	Seeds / pod	100-Seed weight (g)	Yield / plant (g)	Seed yield (kg/ ha)	Harvest index
Annigiri	I_I	22.83	1.36	22.03	7.17	980.40	0.38
	Io	18.57	1.25	21.69	5.04	652.70	0.23
		(-23.07)	**(-8.34)**	**(-1.54)**	**(-29.71)**	**(-33.43)**	(-39.47)
BARI chola-4	I_I	29.30	1.54	13.12	8.01	1090.00	0.44
	Io	24.60	1.47	12.73	6.48	779.20	0.40
		(-16.04)	**(-4.73)**	**(-2.97)**	**(-19.08)**	**(-28.51)**	**(-9.02)**
BARI chola-6	I_I	41.70	1.75	18.18	11.09	1010.00	0.40
	Io	22.67	1.56	17.89	6.50	694.60	0.36
		(-45.64)	**(-10.81)**	**(-1.76)**	**(-41.39)**	**(-31.23)**	**(-10.74)**
ICCV 92501	I_I	28.27	1.97	19.20	7.69	1410.00	0.75
	Io	17.33	1.47	17.86	5.89	918.70	0.45
		(-38.70)	**(-25.64)**	**(-6.98)**	**(-23.32)**	**(-34.84)**	**(-40.00)**
ICCV 92065	I_I	40.63	1.84	16.13	10.55	1765.10	0.55
	Io	31.53	1.51	15.20	7.69	995.20	0.36
		(-22.40)	**(-18.07)**	**(-5.77)**	**(-27.10)**	**(-43.62)**	**(-33.73)**
ICCV 94912	I_I	29.30	1.45	27.40	9.80	1465.00	0.44
	Io	17.15	1.30	25.13	6.20	624.50	0.24
		(-41.47)	**(-10.53)**	**(-8.28)**	**(-36.78)**	**(-57.37)**	**(-46.27)**
ICCV 94918	I_I	19.87	1.25	26.29	7.26	971.90	0.39
	Io	17.67	1.16	25.31	5.39	648.80	0.22
		(-11.07)	**(-7.72)**	**(-3.73)**	**(-21.62)**	**(-33.24)**	**(-27.44)**
ICCV 94923	I_I	27.27	1.24	24.06	8.41	1144.30	0.33
	Io	20.50	1.15	23.86	5.59	775.10	0.30
		(-24.83)	**(-6.92)**	**(-0.08)**	**(-33.52)**	**(-32.26)**	**(-22.23)**
CV %		2.24	6.18	2.20	8.23	12.10	15.53
LSD at α 0.05		0.9680	0.1496	0.7498	0.9965	19.70	0.1058

** Value in the parentheses indicates percent decrease in yield and yield contributing characters due to non-irrigated condition compared irrigated

** I_I and I_0 denote irrigated and non-irrigated treatments, respectively.

From the findings of the study it was concluded that the moisture stress at flowering and pod filling stages affected both RLD and root mass at different soil depths, resulting change in shoot mass, RLWC, yield and yield contributing characters. RLD was seemed to be important character to cope with moisture stress and maintaining yield. Genotypes, which attended high RWD, exhibited less seed yield and HI. High root weight at expense of root length seemed to associate with low yield under moisture stress situation. Though the genotypes ICCV 92065, ICCV 94912 and ICCV 92501 performed better under irrigated condition but the first two had lower yield under moisture stress condition. Under moisture stress condition, genotypes BARI chola-6, ICCV 94923 and Annigiri proliferated roots as well as maintained an apparent moderate equilibrium between RLD and RWD at different soil depths, which was manifested in less reduction in yield and HI. In this regard BARI Chola-4, although moderate yielding, proved to be the most promising genotype in terms of yield and harvest index, and BARI chola-6, ICCV 92501 and ICCV-94923 were closely following it. However, if drought stress situation was considered as usual scenario, ICCV-92065, ICCV-94912, and ICCV-92501, might be termed to have good response to supplemental irrigation if yield was not to be considered.

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