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Effect of irrigation regimes and cultivars on crop biomass and root length density of direct dry- seeded rice (*Oryza sativa* L.)

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Abstract

The direct seeded rice is considered as an alternative to control ground water depletion and reducing cost of labour. To test this hypothesis the field investigation was carried out at research farm of the Department of Soil Science, Punjab Agricultural University Ludhiana, Punjab, India. The experiment comprised of 12 treatments combination viz; three cultivars in main plot (PR 114, PR 115 and PR 120) and four irrigation regimes (10, 20, 30 kPa and fixed 6 days interval) in sub plots. I. At 60 days after sowing (DAS) the average biomass across irrigation treatments was significantly higher in PR 120 and PR 115 over the cultivar PR 114. The biomass recorded with PR 120 was about 2.5 times and PR 115 was about 1.6 times higher than the PR 114 which recorded 0.98 t ha^{-1}. The average biomass decreased progressively with increasing soil matric suction and it was lowest in 6 DI plots (0.9 t ha^{-1}) and highest in 10 kPa plots (2.5 t ha^{-1}). The cultivar PR 120 registered significantly highest number of tillers m^{-2} (492 No's) than the cultivar PR 114 (452 No's) and PR 115 (432 No's). The numbers of tillers m^{-2} in different irrigation treatments varied from 425 to 481. The grain weight was significantly highest (22.1 g) in PR 120 as compared to PR 115 and PR 114 which were at par. The straw yield of rice varied from 6.5 t ha^{-1} to 7.3 t ha^{-1} in various irrigation regimes. The cultivar PR120 recorded significantly highest straw yield. The root length density (RLD) was highest (28.8 cm x10^{6} cm^{-3}) in PR 120 followed by PR 115 (21.6 cm x10^{6} cm^{-3}) and PR 114(19.2 cm x10^{6} cm^{-3}). The RLD was highest in 6 DI plots followed by 10, 20 and 30 kPa plots in the surface layer. However, the trend reversed in 15-30 cm soil layer where it was highest in 10 kPa plots and lowest in 6 DI plots.

Key words: Crop biomass, direct dry- seeded rice, paddy straw yield, root length density, rice cultivars, irrigation regimes

Introduction

Conventional practices of rice cultivation require more water for puddling operation and cause high losses due to surface evaporation and percolation. Water resources are diminishing and it has become limited factor in rice production (Farooq *et al.,* 2009). Increasing labour cost further necessitated the search for alternative management method to increase water productivity in rice cultivation. Current levels of groundwater extraction are more in Northwest India (Hira and Khera, 2000). In central Punjab, the rate of fall in ground water increased from 0.2 m y^{-1} during 1973-2000 to about 1 m y^{-1} during 2001-2006 (Humphreys *et al.,* 2010). This fall has resulted in an increased energy requirement and cost of pumping ground water, increased tube well and installation cost and deteriorated the groundwater quality (AICRP, 2009; Kamra *et al.,* 2002).

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In south Asia, common practice of establishing rice is through puddling followed by seedling transplanting. Puddling helps in reducing water losses through percolation (Kukal and Aggarwal, 2002) and controlling weeds by water stagnation in rice fields (Kukal and Sidhu, 2005). But being costly, cumbersome and time & water-consuming, it results in degradation of soil and other natural resources and subsequently poses difficulties in seedbed preparation for succeeding crop in rotation. Breaking of soil aggregates, alteration of particle orientation and development of hard pan at a depth of 15-25 cm (Singh *et al.,* 2009; Kukal and Aggarwal, 2003) impede root growth of wheat (Boparai *et al.,* 1992; Kukal and Aggarwal, 2003). Also labour scarcity and drudgery among women workers are some of the other disadvantages associated with puddle-transplant rice. Therefore, to get rid of puddling or transplanting or both, efforts are required to explore the possibilities for adopting other crop establishment techniques in rice like direct seeding under unpuddled conditions. Direct seeding rice (DSR) has received much attention because of low water-input demand. Direct seeding has been principal method of rice establishment since 1950's (Pandey and Velasco, 2005). It refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting from the nursery. The DSR is a resource conservation technology as it uses less water with high efficiency and incurs low labour expenses (Bhuiyan *et al.*, 1995). An ideal type cultivar has contributed remarkably to increase rice yield. Rice cultivars with fewer tillers, lower panicle weight with thick roots and culms are suitable for DSR (Won *et al.*, 1996). Early heading rice varieties with better drought tolerance are better suited for dry-seeded rice (Gines *et al.*, 1978). Photoperiod-insensitive cultivars for drought-prone areas may also perform well under the DSR system. Till date, no specific cultivars have been found suitable for DSR. Existing varieties used for puddle transplanted rice (PTR) do not appear to be well suited for seedling growth. As a result it requires 2-3 times higher seed rate to obtain optimal plant population. The DSR is a major opportunity to change production practices to attain optimal plant density and high water productivity in water scare areas. However, appropriate water management, optimum plant population, short duration varieties and more efficient weed management particularly during early growth stages are some of the factors to achieve satisfactory yields. Keeping these points in mind a study was carried out to test the performance of cultivars and irrigation regimes under direct dry- seeded rice in medium textured soil.

Materials and Method

The field study was conducted at Research Farm, Department of Soil Science, Punjab Agricultural University, Ludhiana, during *kharif* 2010. The site is situated at 30° 56' N latitude and 75° 52' E longitude with a mean height of 247 meter above the mean sea level. The average annual rainfall of the area is 600-700 mm, of which about 80 per cent is received during July to September. The meteorological data collected from observatory situated about 2 km away from the research experiment. The experimental field was under rice-wheat rotation for the last three years. After wheat harvest field was irrigated in the last week of May and disked once and cultivated twice followed by planking at field capacity so as to get good seed bed. Pre-sowing irrigation was given four days prior to sowing. The treatments comprised of different cultivars viz. (i) PR 114 (Long duration) (ii) PR115 (Short duration) and (iii) PR120 (medium duration) as main plots and intermittent irrigation on the basis of soil matric suction viz. (i) 10 kPa, (ii) 20 kPa, (iii) 30 kPa and (iv) on fixed six day interval (6 DI) as sub-plots. The treatments were replicated thrice in split plot design with plot size was 4.6 m X 4.1 m. The surface soil of the experimental site contained 77% sand and 11.8% silt, had pH 8.0, EC 0.3 dS m^{-1}, organic carbon content 0.38%, available P and K contents 12.9 and 146.1 kg ha^{-1}, respectively. The sowing of direct dry- seeding was done on June 9th, 2010. Fertilizers and other agronomic practices were followed as per the package of practices recommended by PAU. Sowing was done manually by a hand drill at depth of 3-4 cm. The vacuum gauge tensiometers were installed in different treatments at 15-20 cm depth for monitoring soil matric suction. Dry matter accumulation was recorded at 60, 90DAS and at near harvest. In each plot five spots were randomly selected and plant biomass was taken to ensure the increase in biomass production overtime. The collected plant biomass was first sun dried and then oven dried at 60°C till constant weight, it was expressed as t ha^{-1}. The number of panicle bearing tillers was counted from middle rows at two spots of one meter row length in each plot and was finally expressed as number of effective tillers m^{-2}. Thousand grains were counted from the produce of each plot. Their weight was recorded using electronic balance in grams. The weight was adjusted to 14 per cent moisture content. The root length density was measured with the help of Delta- T SCAN generic method. The sampling was done for measurement of root length (Kirchhof and Pendar 1993). The sample was spread in tray before scanning. After getting the good image, analysis was done. The total length of root was divided by volume of soil from which root was extracted. It was expressed in root length per unit soil volume (cmx10^6 cm $^{-3}$). Bundle weight was recorded after complete sun drying, before threshing and straw weight was obtained after deducting grain weight from the whole bundle weight, which was expressed in t ha^{-1}. Statistical analysis of the data collected on different growth stages of crop and at harvest was done as per Cochran and Cox (1967). The significance of differences among the treatments was judged by analysis of variance (ANOVA) in split plot design. The critical difference at 5 per cent level of significance was worked out wherever, necessary discriminating the treatment effect from the chance effect.

Results and Discussion

Crop biomass

The crop biomass recorded on dry weight basis at 60 DAS, 90 DAS and near maturity was significantly affected by cultivars and irrigation levels (Table 1). At 60 DAS the average biomass across irrigation treatments was significantly higher in PR 120 and PR 115 over the cultivar PR 114. The biomass recorded with PR 120 was about 2.5 times and PR 115 was about 1.6 times higher than the PR 114 which recorded 0.98 t ha^{-1}. The average biomass decreased progressively with increasing soil matric suction and it was lowest in 6 DI plots (0.9 t ha^{-1}) and highest in 10 kPa plots (2.5 t ha^{-1}). The biomass recorded at this stage was higher by 0.4, 1.3 and 1. 6 t $ha^{-1}$with irrigation treatments of 30, 20 and 10 kPa matric suction, respectively over crop irrigated at 6 Day interval. The differential irrigation and cultivars interacted significantly to effect biomass at 60 DAS. This was due to variable response recorded in various cultivars. At 90 DAS the cultivar PR 120 recorded significantly higher biomass (3.4 t ha^{-1}) than cultivar PR 114 which recorded 2.7 t ha^{-1}. This improvement in biomass with cultivar PR 120 was 24 per cent over PR 114. The biomass obtained at this stage was highest with 10 kPa (4.2 t ha^{-1}) and lowest in 30 kPa (2.1 t ha^{-1}) irrigation treatment. The biomass data recorded with 30 kPa and 6 DI irrigation plots were at par. However, the improvement in biomass with 20 and 10 kPa matric suction was 1.2 and 2 t ha^{-1}, respectively over the value of 2.2 t ha^{-1} with 6 DI irrigation treatments. Like 90 DAS stage, the biomass at maturity also observed similar trend among cultivars. The cultivar PR 120 recorded significantly highest biomass (13.2t ha^{-1}) as compared to cultivar PR 115 and PR 114 which recorded statistically similar values (Table 1). The irrigation treatments significantly affected the crop biomass and it was maximum in 20 kPa and minimum with 6 DI irrigation treatments. The average biomass recorded with 10 kPa and 20 kPa did not differ significantly but it significantly declined when soil matric suction further increased to 30 kPa and also in plots irrigated at 6 days interval. Similar observations were recorded by Kukal *et al* (2005) who reported that increase in soil matric tension to 25 and 30 kPa resulted in significant decrease in crop biomass at harvest stage. A significant interaction was observed between the cultivars and irrigation in respect of crop biomass decrease at harvest. The interaction is attributed to variable response of irrigation to cultivars. The biomass recorded with various irrigation levels imposed did not show significant decline with cultivar PR 120 while in other two cultivars there was a significant reduction in biomass yield with increase in matric suction and fixed interval of 6 days. It is concluded from the above that cultivar PR 120 was relatively more susceptible to moisture stress. The biomass recorded in PR 120 was the highest and it may be because of higher yield potential of this cultivar as compared to other cultivars (Anonymous 2010). The graphical presentation of biomass recorded in different irrigation regimes is given in Fig. 1. Interestingly, the crop biomass during the initial stage of plant growth was similar in 10 and 20 kPa plots but it was higher than 30 kPa and 6 DI plots, irrespective of the cultivars. The biomass in 30 kPa and 6 DI plots remained similar at all the recorded growth stages. The biomass in 10 kPa plots was higher at 90 DAS but became similar to that in 20 kPa plots at harvest stage. It was revealed that the crop biomass obtained with cultivar PR 120 was higher throughout the growing season than recorded with cultivar PR 115 and PR 114 (Fig 2). However, PR 114 and PR 115 behaved similar with respect to crop biomass at all the recorded growth stages.

Number of tillers

The number of tillers per square meter observed at maturity was significantly influenced by cultivars and irrigation treatments (Table 2). The cultivar PR 120 registered significantly highest number of tillers m^{-2} (492 No's) than the cultivar PR 114 (452 No's) and PR 115 (432 No's).

Table 1: Crop biomass (t ha^{-1}) as affected by irrigation regimes and cultivars at different growth stages

Irrigation scenario	Cultivars			
	PR114	**PR115**	**PR120**	**Mean**
		60 DAYS		
10 kPa	1.4	2.0	4.0	2.5
20 kPa	1.5	2.0	3.0	2.2
30 kPa	0.58	1.5	1.7	1.3
6 DI	0.52	0.9	1.3	0.9
Mean	0.98	1.6	2.5	
LSD (0.05)	V= 0.25, I= 0.17, V X I= 0.3			
		90 DAYS		
10 kPa	3.7	4.1	4.8	4.2
20 kPa	3.0	3.2	3.8	3.4
30 kPa	2.1	2.0	2.3	2.1
6 DI	2.0	2.3	2.5	2.2
Mean	2.7	2.9	3.4	
LSD (0.05)	V= 0.21 , I= 0.31, V X I= NS			
	Near maturity			
10 kPa	12.2	12.4	13.2	12.6
20 kPa	12.2	12.6	13.4	12.7
30 kPa	11.2	11.5	13.0	11.9
6 DI	10.8.	10.7	13.2	11.6
Mean	11.6	11.8	13.2	
LSD (0.05)	V= 0.59, I= 0.34, V X I= 0.64			

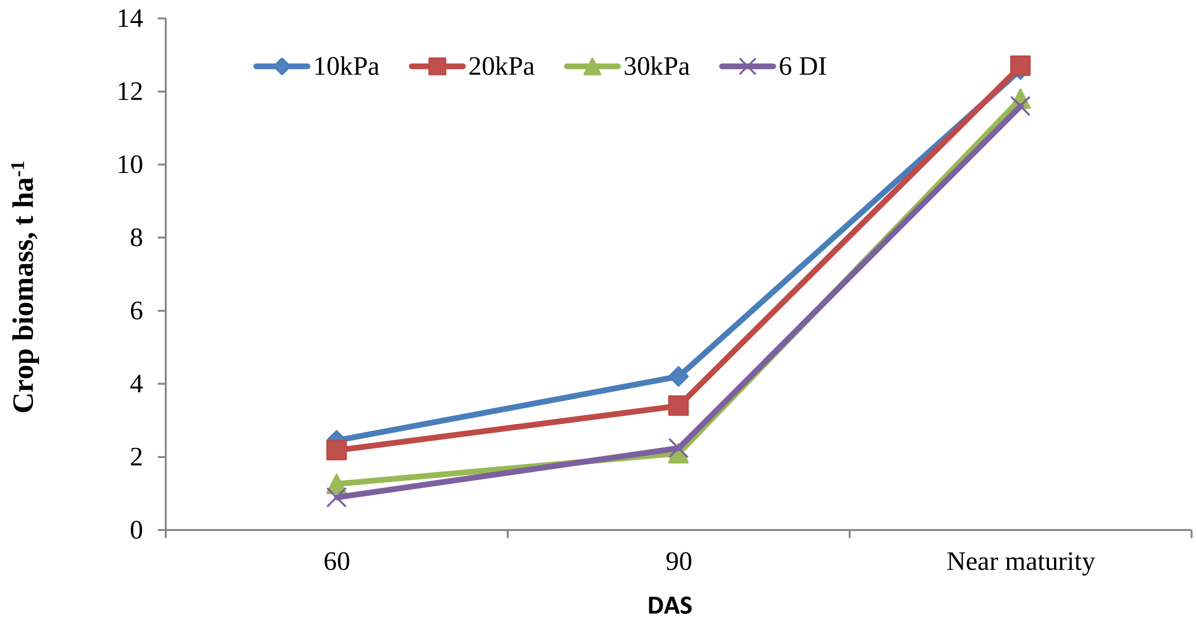

Fig 1: Crop biomass under different irrigation treatments at various growth stages.

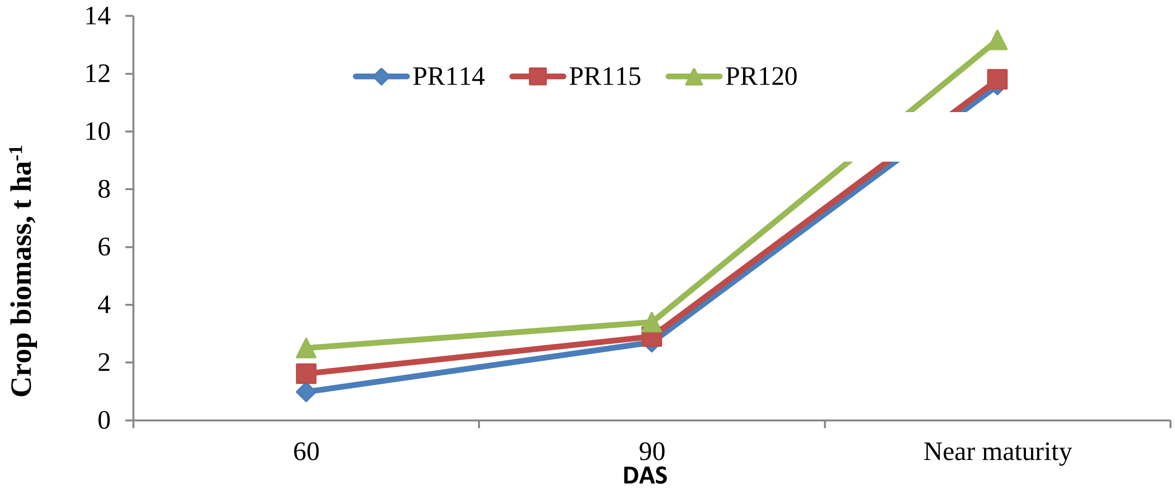

Fig 2: Crop biomass for various cultivars at different growth stages.

Table 2: Number of tillers (No's m^{-2}) under different irrigation regimes and cultivar

Irrigation scenarios	**Cultivars**			
	PR114	**PR115**	**PR120**	**Mean**
10 kPa	487	440	518	481
20 kPa	484	438	512	478
30 kPa	418	404	453	425
6 DI	418	411	463	430
LSD (0.05)	V= 29.02, I= 14, V X I= NS			

Number of tillers observed to be at par in PR 114 and PR 115. The numbers of tillers m^{-2} in different irrigation treatments varied from 425 to 481. The irrigation treatments based on 10 and 20 kPa matric suction produced significantly higher numbers of tillers than 30 kPa and 6 DI irrigation treatments. The number of tillers recorded in 10 and 20 kPa were similar and were also similar with 30 kPa and 6 DI irrigation treatments. Sudhir-Yadav *et al* (2011) reported maximum number of tillers in DSR which occurred at around maturity.

Thousand grain weight

The test weight of thousand grains recorded at harvest was significantly influenced by cultivars and irrigation levels (Table 3). It was varied from 18.4 to 23.2 g in different cultivars and irrigation treatments. The grain weight was significantly highest (22.1 g) in PR 120 as compared to PR 115 and PR 114 which were at par. The thousand grain weight was highest in 10 kPa (21.3 g) plots followed by 20 kPa (21.1 g), 30 kPa (20.7 g) and 6 DI (19.5 g). Data revealed that crop irrigated on the basis of 10 and 20 kPa irrigation schedule produced similar thousand grain weight.

Straw yield

The straw yield of various cultivars in relation to differential irrigation regimes is given in Table 4. The straw yield of rice varied from 6.5 t ha^{-1} to 7.3 t ha^{-1} in various irrigation regimes. The cultivar PR120 recorded significantly highest straw yield. However, no interaction was observed between cultivars and irrigation levels to affect the straw yield.

Root length density

The root length density (RLD) recorded with root scanner as influenced by various irrigation levels and cultivar is given in Table 5 and Fig.3. The RLD recorded in cm x10^6 cm $^{-3}$ was higher in top 15 cm soil layer. It was recorded highest value (28.8 cm x10^6 cm $^{-3}$) with PR 120 followed by (21.6 cm x10^6 cm $^{-3}$) in PR 115 and (19.2 cm x10^6 cm $^{-3}$) in PR 114. The total RLD also followed the same trend as observed in surface layer (0-15 cm) irrespective of irrigation treatments. Among various irrigation treatments total RLD and RMD in 0-15 cm soil layer was recorded to be highest in PR 120 as compared to other cultivars. The higher RLD with cultivar PR 120 may be due to the reason that the plant biomass of this cultivar including paddy yield was higher than that with PR 115 and PR 114. The RLD was highest in 6 DI plots followed by 10 kPa, 20 kPa and minimum in 30 kPa plots (Fig 4) in 0-15 cm layer. However, the trend reversed in 15-30 cm soil layer where RLD was highest in 10 kPa plots. It was similar in 20 and 30 kPa plots and recorded minimum in 6 DI. In 30-45 cm soil layer the RLD was highest in 30 kPa perhaps because of water stress conditions due to delayed irrigation.

Table 3:Thousand grain weight (g) of different cultivars as affected by irrigation levels

Irrigation scenario	Cultivars			
	PR114	PR115	PR120	Mean
10 kPa	20.4	20.3	23.2	21.3
20 kPa	19.9	21.0	22.4	21.1
30 kPa	19.7	20.8	21.6	20.7
6 DI	18.8	18.4	21.4	19.5
LSD (0.05)	V=1.27, I=1.04, V X I= NS			

Table 4: Straw yields (t ha^{-1}) of different cultivars as affected by different irrigation regimes

Irrigation scenario	Cultivars			
	PR114	PR115	PR120	Mean
10 kPa	7.1	6.9	7.5	7.2
20 kPa	7.0	7.1	7.8	7.3
30 kPa	6.4	6.7	7.3	6.8
6 DI	6.3	5.9	7.4	6.5
Mean	6.7	6.7	7.5	
LSD (0.05)	V=0.45, I= 0.27, V X I= NS			

Table 5:Root length density (cmx10^6 cm^{-3}) as affected by cultivar and irrigation regimes

Soil depth	PR 114				
(cm)	10 kPa	20 kPa	30 kPa	6 DI	Mean
0-15	21.7	18.0	15.0	21.8	19.2
15-30	5.7	1.6	4.0	0.9	3.1
30-45	1.3	.90	2.8	1.6	1.7
Mean	9.6	6.9	7.3	8.1	
PR 115					
0-15	21.6	23.6	17.8	23.5	21.6
15-30	3.3	1.7	2.0	0.8	2.0
30-45	1.0	0.8	3.6	0.9	1.5
Mean	8.6	8.7	7.8	8.4	
PR 120					
0-15	24.2	24.3	32.3	34.2	28.8
15-30	4.3	1.4	1.7	1.0	2.1
30-45	1.3	1.6	5.0	1.7	2.4

Mean	9.9	9.1	13.0	12.2

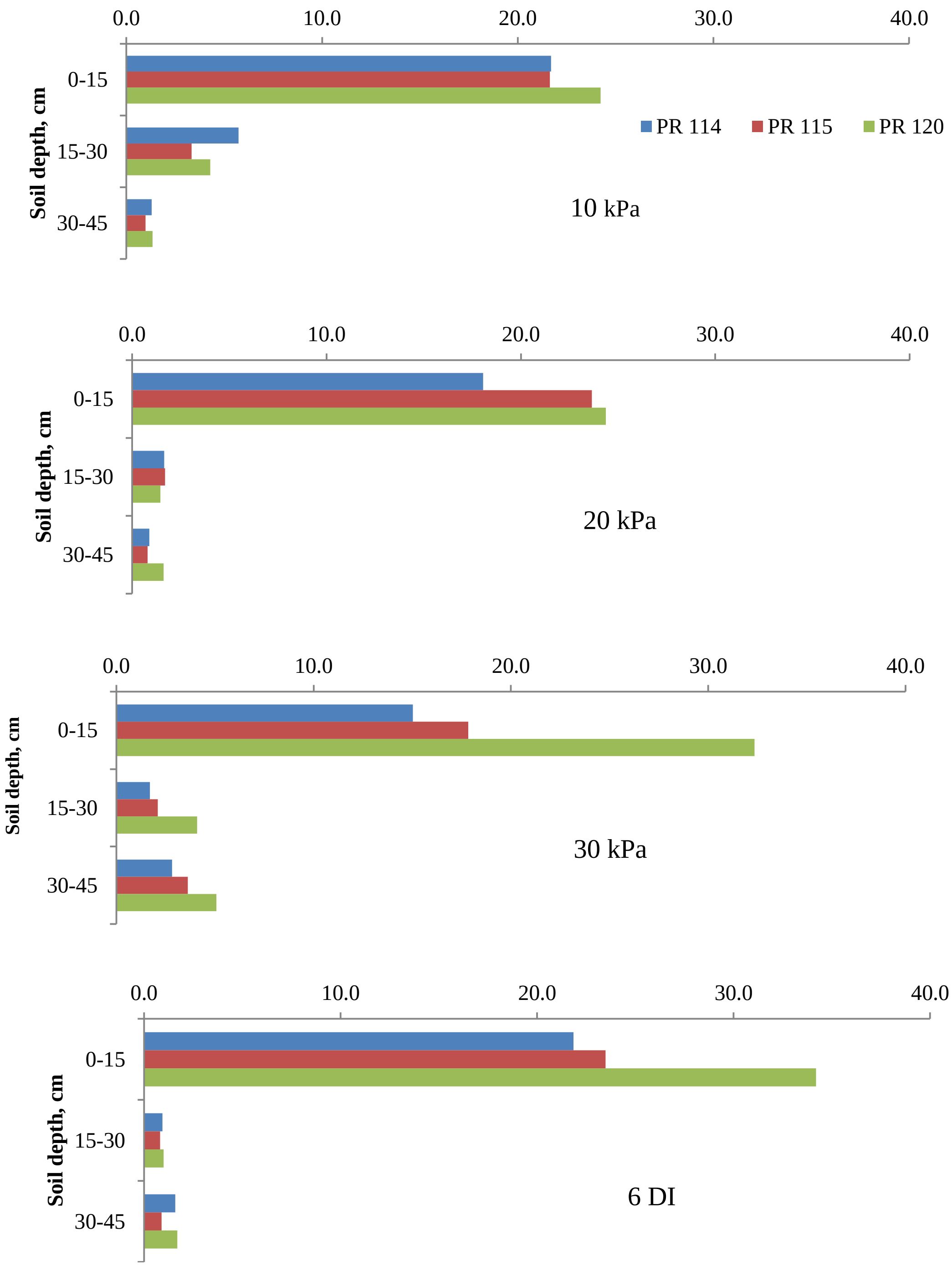

Fig 3: Root length density (RLD) in different soil layers under various cultivars for different irrigation treatments

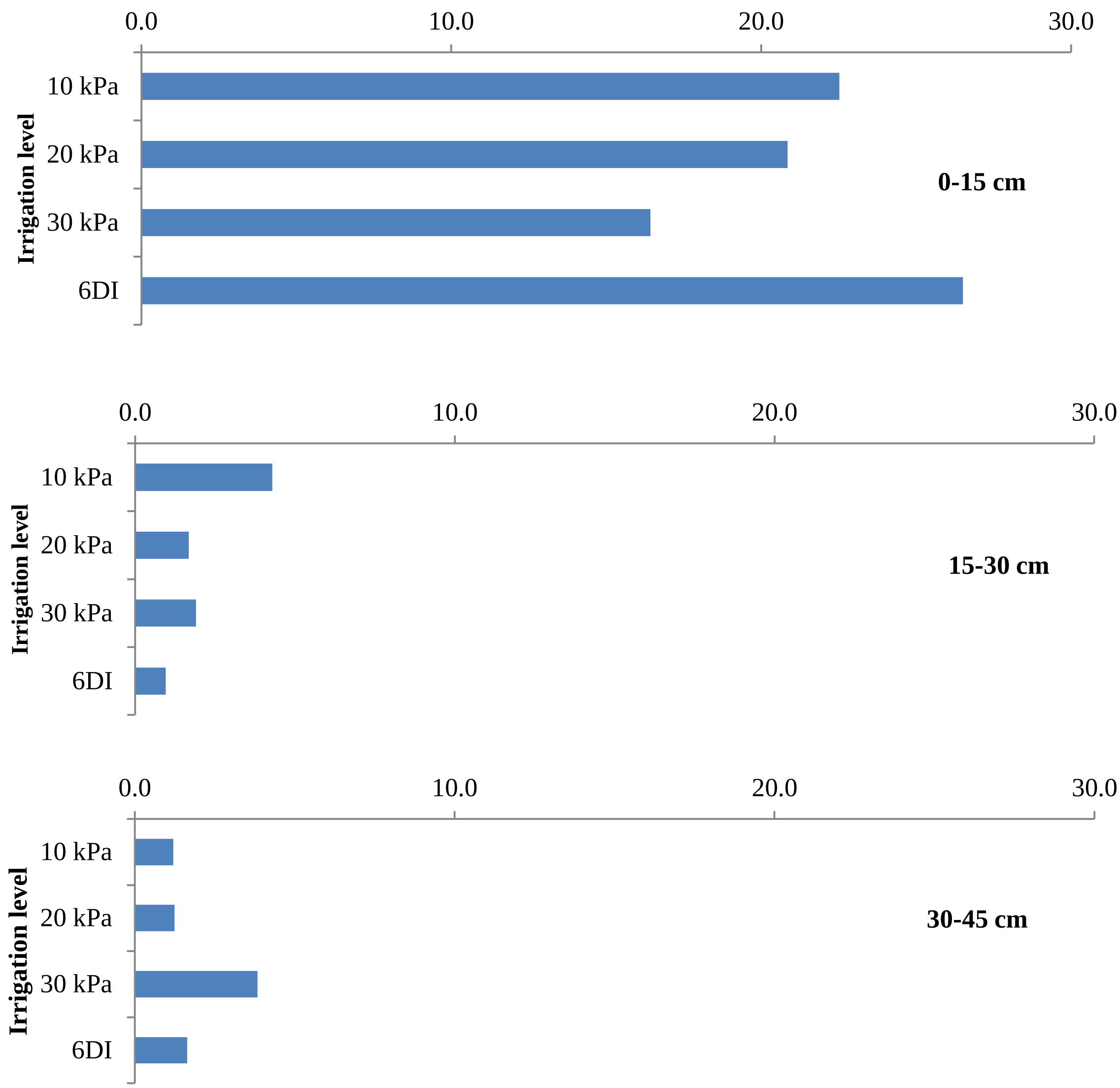

Fig 4: Root length density (RLD) as affected by differential irrigation for different depths

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