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Root Growth of Sorghum (*Sorghum bicolor*), Castor (*Ricinus communis*) and Pigeonpea (*Cajanus cajan*) Exposed to Intermittent Drought

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ABSTRACT : Sorghum, castor and pigeonpea were grown under irrigated and rainfed conditions during *kharif* 1990 to study response of root growth under limited water condition. Water stress decreased root growth and biomass in sorghum. In castor, water stress altered root-shoot ratio in favour of root growth. In pigeonpea, it decreased total root dry weight but increased in root volume by reduction in root density. By increase in root growth in castor and volume in pigeonpea, the adaptive responses were documented.

Moisture stress in dryland agriculture adversely affects crop production. The success of crop production under rainfed environments depends on the ability of crops to efficiently explore more soil volume and efficiently use the explored soil water. Crop productivity also depends on the intensity, duration and timing of water stress. The most important attribute conferring the ability of a crop to cope with water stress is the distribution and function of its root system under water limiting condition. Work relating to root growth under dryland conditions is limited (O' Toole and Bland, 1987 ; Klepper and Rickman, 1990) due to the problems associated with the separation of roots from dry soil and other operational problems. Recently, new techniques involving use of mini rhizotrons to monitor in situ root growth and also use of computer. assisted tomography in studying water movement around roots are available (Alymore, 1993). But these techniques are very expensive and not available routinely. Inspite of these limitations it is desirable to understand the root growth and its characteristics and function under limited water conditions, and hence the present study was undertaken.

MATERIALS AND METHODS

Three important dryland crops viz., a cereal, an oilseed and a pulse crop represented by CSH-6 in sorghum, SHB-18 in castor and HY-2 in pigeonpea respectively were grown under rainfed and stress-free conditions in Alfisols at the institute research farm during the rainy season of 1990. All the crops were sown on 14th of June 1990. Stress-free conditions were maintained by giving 5 cm of supplemental irrigation whenever the soil moisture depleted to 50 % of the available moisture. Experimental site had neutral pH, low in available N and P and medium in K, and the soil depth was 30-60 cm.

During the cropping season, sorghum, castor and pigeonpea received 387, 560 and 563 mm rainfall respectively. The occurrence of water stress periods and the corresponding growth stages of the crops were analysed and are given in Fig.1. Sorghum experienced 2 weeks of moisture stress in early vegetative and mid flowering growth stages. Pigeonpea experienced moisture stress at early (vegetative), mid (flowering) and terminal (grain filling) stages with 15, 16 and 12 days of rainless period respectively. In castor, moisture stress occurred at the flowering of primaries (12 days), formation of secondaries and quaternaries (Fig.2) apart from the earlier rainless periods described. Five plants were selected for taking root samples. Soil was dug to extract maximum roots up to a depth of 1 m. The soil was separated from the roots by directing gentle spray of water using a manually operated water sprayer. The root volume of plants was determined by water displacement method. The root dry weight was determined by drying the roots in an hot air oven at 60° C till consistent weight was obtained. For determining the root shoot ratio, the above ground dry matter of plants was also determined similarly.

RESULTS AND DISCUSSION

Monitoring of leaf area of these crops both under rainfed and stress-free conditions during their life cycle showed that the rainfed treatments maintained lower leaf area than their stress-free counterparts (Table 1). This confirmed that rainfed treatments were exposed to water deficits and hence had lesser leaf area.

Root weight

The root weight (g) of crops was more under stress-free condition than the rainfed. The extension of root and branching decreases with drying of soil. In the long duration crops of castor and pigeonpea, the differences in the initial stages of development of growth were not significant. However, in sorghum the differences were evident (Table 1). The root weight of castor under stress-free conditions increased significantly by 8, 11, 15, 36 and 3 % compared with the rainfed environment at 30, 60, 90, 120 and 150 days after sowing. The differences between rainfed and stress-free conditions were maximum during the development of primaries in castor. The root weight of rainfed pigeonpea decreased by 30, 8, 27, 30 and 25 % than the stress-free pigeonpea at 30, 60, 90, 120 and 150 days after sowing. Sorghum in the rainfed environment reduced the root weight by 50, 16, 17 and 8 % at 30, 60, 90 and 120 days after sowing compared with stress-free condition. The root system of sorghum differed with castor and pigeonpea as it had the maximum difference between rainfed and irrigated treatments in the early stages. This could be due to confining of sorghum root system to the top layers and effect of soil moisture stress during rainless period compared to deeper layers.

Root volume and density

In sorghum the root volume was higher under stress-free condition throughout the growing period. Similarly, castor also had a higher root volume under stress-free condition. In pigeonpea, water stress increased the volume though the root weight was less under stress. Accordingly, the root density of stressed pigeonpea increased the root volume. This would be an important adaptation for pigeonpea because during periods of stress the limited amount of dry matter made available to roots would be used to increase the root volume and thereby explore more soil volume for moisture. This also could be one of the reasons contributing to the lesser coefficient of variation in the yield of pigeonpea over time compared with castor in drylands (Rao *et al.*, 1993). The root density of castor was higher in water stressed treatment during vegetative stage due to higher diversion of dry matter to roots during water stress period. There were no differences in root density of during latter parts of reproductive stage.

Table 1. Effect (
sorgh

SF
Leaf area (cm^2/ pl
Castor
Pigeonpea
Sorghum
CD for crops
CD for stress periods
CD for CxS
Root density (g
Castor
Pigeonpea
Sorghum .(
CD for crops 0
CD for stress periods 0
CD for CxS 1
Root dry weight (
Castor 5
Pigeonpea
Sorghum
CD for crops
CD for stress periods
CD for CxS
SF : Stress-free

Table 1. Effect of stress on leaf area, root density and root weight of castor, pigeonpea and sorghum during crop growth period

	Days after sowing									
	30		60		90		120		150	
	SF	S	SF	S	SF	S	SF	S	SF	S
Leaf area (cm^2/ plant)										
Castor	773	354	6136	4083	6547	3878	6215	3215	3834	3186
Pigeonpea	191	181	2442	1938	5500	4673	11458	9314	8436	8130
Sorghum	896	960	3663	3268	3163	2807	2289	1965	---	---
CD for crops	106		892		1158		1650		1132	
CD for stress periods	75		564		819		1166		925	
CD for CxS	150		1261		1638		2330		1602	
Root density (g/ cc)										
Castor	4.3	2.3	52.6	39.0	63.8	48.5	100.0	51.6	110.0	58.7
Pigeonpea	1.3	1.2	17.0	16.5	39.6	48.0	110.0	59.0	89.7	65.3
Sorghum	16.2	11.7	96.5	88.3	116.3	100.0	87.1	85.0	---	---
CD for crops	0.8		2.4		3.3		3.8		2.5	
CD for stress periods	0.6		1.5		2.3		2.7		2.0	
CD for CxS	1.1		3.4		4.5		5.4		3.5	
Root dry weight (g/ plant)										
Castor	5.0	4.6	11.6	10.4	13.6	11.8	17.7	13.1	26.2	19.9
Pigeonpea	1.1	0.8	10.7	9.9	16.3	12.8	45.1	35.6	45.9	36.7
Sorghum	1.7	1.1	22.6	19.5	27.3	23.4	26.6	24.6	---	---
CD for crops	0.3		0.5		1.1		2.6			4.0
CD for stress periods	0.2		0.4		0.8		1.4			3.4
CD for CxS	---		0.8		1.5		2.5			---

SF : Stress-free S : Stress CD : Critical difference at 5 % level

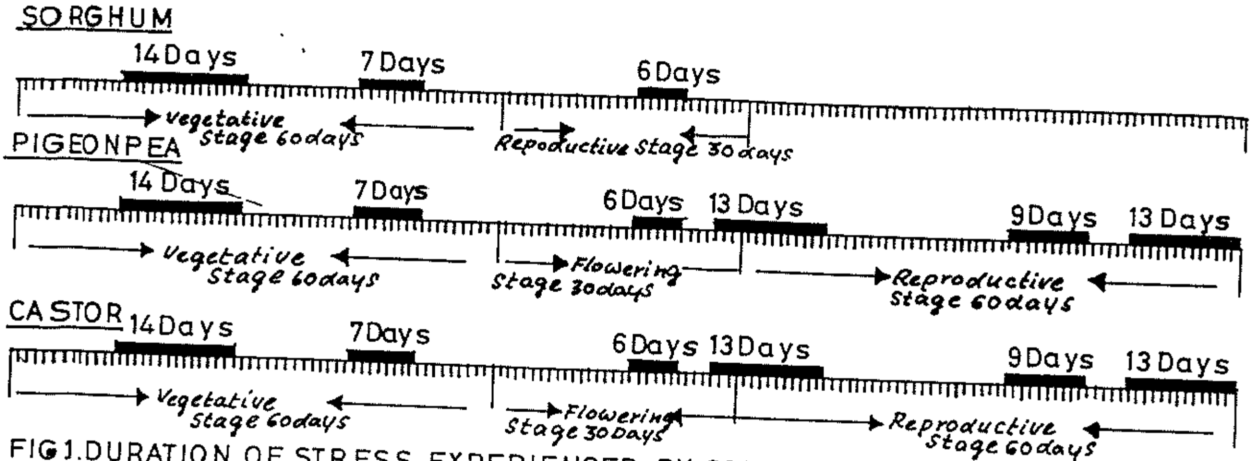

FIG 1.DURATION OF STRESS EXPERIENCED BY SORGHUM PIGEONPEA and CASTOR

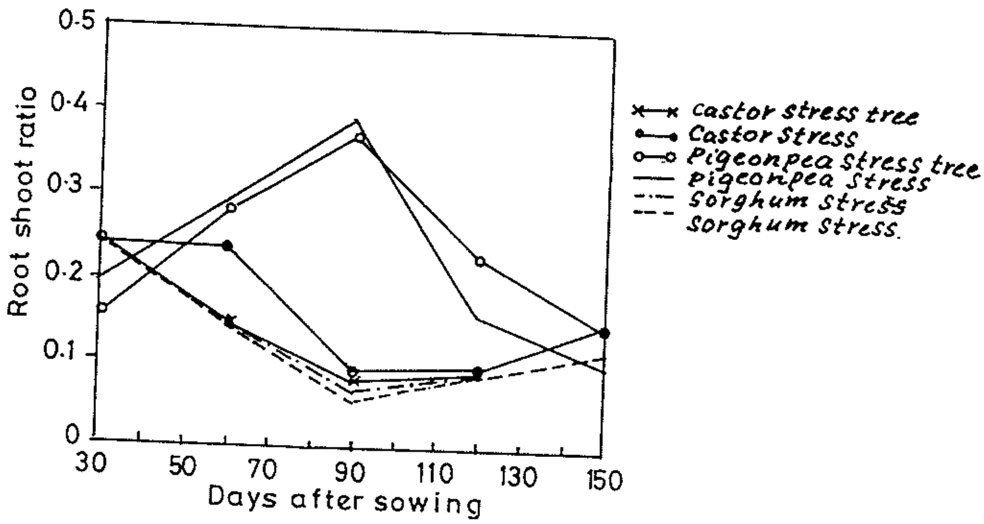

FIG.2.INFLUENCE OF MOISTURE STRESS ON ROOT SHOOT RATIO OF SORGHUM PIGEONPEA and CASTOR

Root shoot ratio

The partitioning
relation to shoot p
coping with drought
made available to th
root growth which c
of the soil for m
reported that drougl
ratio of sorghum b
free condition. In ca
diverted to the roo
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increased soil water
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pigeonpea up to 90
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However, during gr
decreased under
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of drought. The phy
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root volume under v
investigated. Pigeo
would adopt novel n
the root density th
volume. The increas

Root shoot ratio

The partitioning of dry matter to roots in relation to shoot plays an important role in coping with drought. The additional dry matter made available to the roots would help in new root growth which could explore deeper layers of the soil for moisture. Passioura (1983) reported that drought increases the root shoot ratio of sorghum between rainfed and stress-free condition. In castor, more dry matter was diverted to the roots under rainfed condition during formation of primaries. Whether this increased allocation of dry matter to roots during water stress in castor lead to an increased soil water accessibility needs to be confirmed. The difference leveled off in later stages. The root shoot ratio, increased in pigeonpea up to 90 days and then decreased up to harvest. Generally the root shoot ratio was not different between rainfed and stress-free condition in pigeonpea up to flowering. However, during grain filling period the ratio decreased under rainfed condition. The contrasting behaviour of these crops could be due to a combination of inherent genetic composition and also the nature and intensity of drought. The physiological consequences of the observation that pigeonpea increases its root volume under water stress is needed to be investigated. Pigeonpea under water stress would adopt novel mechanisms like decreasing the root density thereby increasing the root volume. The increased root volume would help the crop in exploring larger soil volume for moisture. It would be worth while to look for degree of variability for this and other such strategies which plants employ to smother the ill effects of drought.

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