DROUGHT STUDIES IN DRY BEAN *(PHASEOLUS VULGARIS L.)*

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Introduction

Dry bean is not a drought tolerant species (Markhart 1985). Nonetheless, the crop is grown over a wide range of habitats where it is exposed to seasonal drought as well as wide fluctuations in available soil moisture. Most dry bean production is on dryland and limited moisture availability is a major factor limiting bean yield levels (Markhart 1985, White and Singh 1991).

Deep penetrating roots with adequate root density throughout the soil profile are required for maximum extraction of moisture from the soil in rainfed environments (Gregory 1988). Studies in many crops (Jordan and Miller 1980, Passioura 1983), including dry bean (Sponchiado et al. 1989), confii the importance of root growth in permitting plants to explore a greater soil volume, thus extracting more moisture, and suffering less drought stress. Sorghum *(Sorghum bicolor)* root density at depths greater than 75 cm was inadequate to extract available soil moisture at that depth and soil moisture was left unused at the end of the cropping season (Jordan and Miller 1980). Accordingly, selecting crop cultivars with high root densities at greater depths may offer an opportunity to select for drought tolerance under rainfed environments. Therefore, evaluation of genotypes for root pattern and rate of root growth may be useful to breeders in selecting genotypes tolerant to drought. The objectives of this study were to:

1) screen dry bean genotypes for genetic variation in rooting pattern under limited soil moisture, and

2) determine the relationship between root pattern and yield under field conditions.

Materials and Methods

Experiment 1

Twenty bean genotypes (Othello, ISB82-114, Nodak, UI 111, Agassiz, GH196-2, UI 114,81-13197, ISB82-354, Fiesta, 5325,6315, Viva, Topaz, 8173-6E, Earliray, 92064, 92121, Agate and 92002) were seeded in polyvinyl acetate (PVC) tubes, one metre long and 10 cm in diameter, placed upright in a pit one meter deep. The pit was located at Preston plots, University of Saskatchewan, Saskatoon. Each PVC tube was cut through longitudinally along one side and taped again. The rooting medium consisted of a mixture of 25% perlite; 25% vermiculite; 40% sand and 10% top soil thoroughly mixed and packed into the tubes to uniform density. Water was added to 50% field capacity before seeding 5 seeds per tube on 25 July 1993. One week after emergence plants were thinned to one per tube. After emergence water was applied to the plants only when plants showed signs of wilting late in the afternoon. A rainout shelter was erected on top of the pit to divert rainfall.

The treatments were arranged in a split-plot design with bean genotype as the main plot and time of sampling (3) as the subplot. Three replications were used. One PVC tube of each bean genotype in each replication was pulled out at the unfolding of the third trifoliolate leaf (V4), the opening of the first flower (R6) and early pod formation (R8). Each tube was held open with small cylinders at the previously lengthwise cut surface and small soil samples for moisture determination were taken at depths of 10, 20, 30, 40, 50, 60 and 70 cm (except at the first sampling). The soil samples were immediately weighed, dried at 120°C for 48 hours and reweighed for gravimetric moisture determination.

The soil core from each tube was cut into successive 10 cm sections and removed. Plant roots were extracted by carefully washing away the rooting media. Root length of each portion was estimated by a modified version of Newman's (1966) line intercept method (Tennant 1975). After measuring root length the root material was dried (80°C for 48 hours) and dry weight was recorded. Root length density was calculated as length of roots (cm) per cm^3 of soil.

The experiment was repeated in the summer of 1994 when 10 selected genotypes (Othello, GH196-2, Agate, 5325, 63 15, Earliray, ISB82-354, Fiesta, UI 111 and Nodak) were used. Five of the selected genotypes had shown good root attributes while the other five had shown poor root attributes in 1993. The methods used were basically the same with the exception that the rooting medium was changed to 50% sand and 50% topsoil.

Experiment 2

Six bean genotypes, three that had shown good root attributes (Othello, GH196-2 and Agate) and three that had shown poor root attributes (Earliray, Fiesta and ISB82-354) in the first experiment were grown under rainfed and irrigated conditions at Saskatoon in 1994. A randomized complete block design with four replication was used. The beans were sown at 55 seeds/m2 in plots 2.4 m long by 1.2 m wide. Galvanized tin strips were placed around irrigated plots which received 25 mm water at early pod fill. Yield was measured in 1.44 m^2 bordered plots. Soil moisture was determined gravimetrically at physiological maturity on core samples taken at intervals of 20 cm within each plot to a depth of 60 cm.

Results

Experiment 1

In the 1993 preliminary experiment, dry bean genotypes differed significantly ($P<0.001$) in root length and root length density at the third trifoliolate leaf stage (Table 1). These significant differences were maintained to the later stages of sampling (Table 2) at which time genotypes also differed significantly in root dry weight. The genotype x depth and genotype x growth stage interactions were not significant, i.e., root depth and growth stage had no differential effects among genotypes.

TABLE **1 -** Effect of genotype on root length, root length density and root dry weight at the V4 stage of bean plant development, 1993

Genotype	Root length (cm)	Root length density(cm/cm3)	Root dry weight(g)
Othello	228	0.29	0.26
ISB82-114	174	0.22	0.25
Nodak	91	0.11	0.15
UI 111	182	0.23	0.23
Agassiz	170	0.22	0.23
GH196-2	285	0.36	0.24
UI 114	158	0.20	0.21
81-13197	264	0.34	0.26
ISB82-354	138	0.18	0.23
Fiesta	183	0.23	0.24
5325	169	0.22	0.21
6315	148	0.21	0.24
Viva	165	0.21	0.24
Topaz	223	0.28	0.24
8173-6E	179	0.23	0.23
Earliary	175	0.22	0.23
92064	0.22	0.17	0.21
92121	217	0.28	0.26
Agate	201	0.26	0.23
92002	235	0.30	0.38
Mean	186	0.237	0.235
S.E.	18.2	0.023	0.021
Signif.	**	**	N.S.
L.S.D.(0.05)	36.0	0.065	

TABLE 2 - Effect of genotype on root length, root length density and root weight averagedover the R6 and R8 stage of bean plant development, 1993

Genotype	Root length (cm)	Root length density(cm/cm^3)	Root dry weight(g)
Othello	245	0.31	0.28
ISB82-114	246	0.31	0.30
Nodak	264	0.34	0.27
UI 111	197	0.25	0.24
Agassiz	276	0.35	0.33
GH196-2	275	0.35	0.30
UI-114	263	0.34	0.30
81-13197	281	0.36	0.29
ISB82-354	187	0.24	0.25
Fiesta	199	0.25	0.26
5325	324	0.41	0.34
6315	303	0.39	0.32
Viva	275	0.35	0.29
Topaz	250	0.32	0.29
8173-6E	275	0.35	0.31
Earliray	188	0.24	0.26
92064	279	0.36	0.33
92121	273	0.35	0.31
Agate	289	0.37	0.33
92002	272	0.35	0.33
Mean	258.1	0.329	0.297
S.E.	21.6	0.0028	0.015
Signif	**	**	**
L.S.D.(0.05)	61.9	0.079	0.042

In 1994 bean genotype did not significantly affect root attributes at the third trifoliolate leaf stage. Subsequently, data from the R6 and R8 stages were analyzed together.

The genotype X depth and genotype X growth stage interactions were significant for root length, root length density and root weight. Othello, GH196-2 Agate, 6315 and 5325 showed more extensive roots with higher root length density and root weight at greater depths compared to Earliray, ISB82-354, Fiesta and Nodak. Figures 1 and 2 show the distribution of root length density and root weight for four bean genotypes, two (GH196-2 and Othello) with good root attributes at greater depths and two (Earliray and ISB82-354) with poor root attributes at greater depths. The former genotypes also showed greater increase in root attributes between flowering and pod filling compared to the latter (Table 3). The distribution of soil moisture within the soil profile (Figure 3) shows that the soil moisture was depleted deeper into the profile at the successively later growth stages.

Experiment 2

Bean genotype had a significant effect on seed yield, days to flower and days to maturity (Table 4). The highest seed yield was recorded for Othello and the lowest for Earliray. In general genotypes which showed good root attributes in the first experiment were late maturing and high yielding in the field. Irrigation had a significant effect on seed yield. Irrigated plots yielded significantly higher than the nonirrigated plots (data not presented). The genotype x water level interaction was not significant. Earliray, the lowest yielding genotype, used less soil moisture by physiological maturity than the rest of the genotypes.

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Figure 1 · Distribution of root length density in the soil profile for four selected bean genotypes, 1994. Data are averaged over the R6 and R8 stages of plant development.

Figure 2 - Distribution of root weight in the soil profile for four selected bean genotypes, 1994. Data are averaged over the R6 and R8 stages of plant development.

Figure 3 - Distribution of soil moisture in the soil profile at the V4, R6 and R8 stages of bean plant development, 1994 (average of 10 genotypes).

TABLE 3 - Effect of genotype and crop development stage on root length density and root weight of bean plants, 1994

Genotype	Root length density (cm/cm3)		Root dry weight (g)	
	R6	R8	R6	R8
Othello	0.24	0.32	0.30	0.32
GH196-2	0.23	0.32	0.26	0.34
6315	0.27	0.37	0.30	0.37
5325	0.24	0.33	0.29	0.34
Earliray	0.22	0.23	0.26	0.29
Fiesta	0.23	0.28	0.27	0.30
ISB82-354	0.23	0.20	0.27	0.24
UI 111	0.17	0.30	0.23	0.33
Nodak	0.19	0.23	0.22	0.25
Mean	0.22	0.29	0.24	0.31
S.E.(Difference)	0.059		0.043	
Signif.	*		**	
L.S.D(0.05)	0.118		0.095	

TABLE 4 Effect of genotype on days to flower, days to physiological maturity, seed yield and soil moisture at physiological maturity of field grown beans, 1994.

Genotype	Seed Yield (kg/ha)	Days to flower	Days to maturity	soil moisture(%)
Othello	2027	54	86	10.7
Agate	1757	53	93	10.3
GH196-2	1774	54	96	8.5
Earliray	1251	48	85	13.5
Fiesta	2041	52	86	9.3
ISB82-354	1560	51	82	9.7
Mean	1740	52	88	10.3
S.E.	120	0.3	0.2	0.76
Signif.	**	**	**	**
L.S.D.(0.05)	347	0.9	0.6	2.67

Discussion

Significant genetic variation for root attributes, presumably related to drought tolerance, was available in the bean genotypes studied. This genetic variation can be used by breeders in developing drought tolerant bean cultivars. However, screening and selecting for rooting depth on a large scale is laborious. Thus, evaluation of root traits may have a potential if restricted to a few promising lines or to parents in a breeding program.

Under field conditions, bean genotypes with extensive root systems were generally later maturing than those with poor root systems. This might present a problem in that selection for deep extensive root systems may lead to a shift toward late maturing material. However, Othello was an exception in that this genotype had good root attributes, matured comparatively early and recorded the highest seed yield.

Conclusions

1. Significant genetic variation for root attributes was observed among bean genotypes screened in the study.
2. Bean genotypes which showed good root attributes were generally late maturing and high yielding under field conditions.

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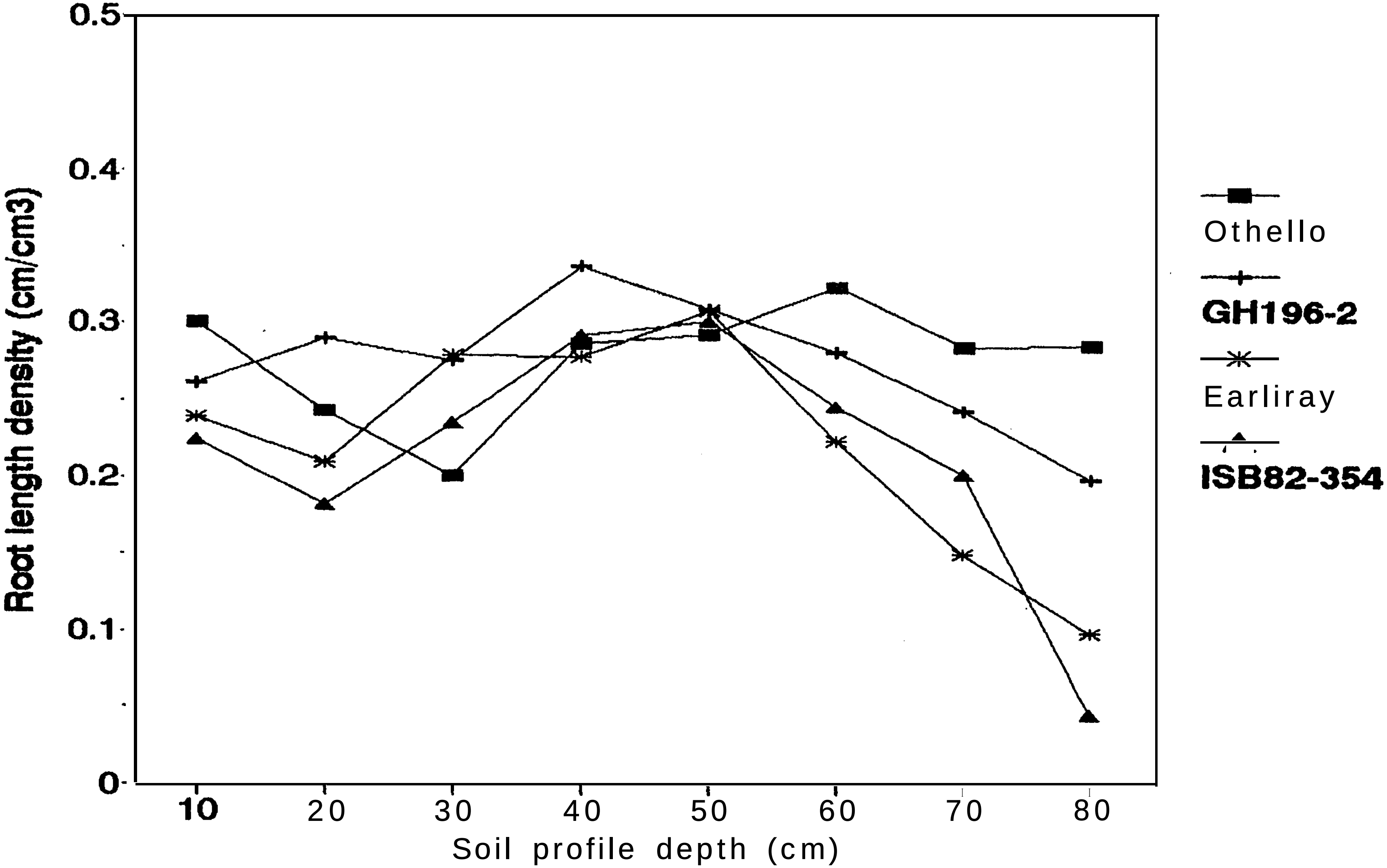

Fig 1 - Distribution of root length density in the soil profile for four selected bean genotypes, 1994. Data are averaged over the R6 and R8 stages of plant development.

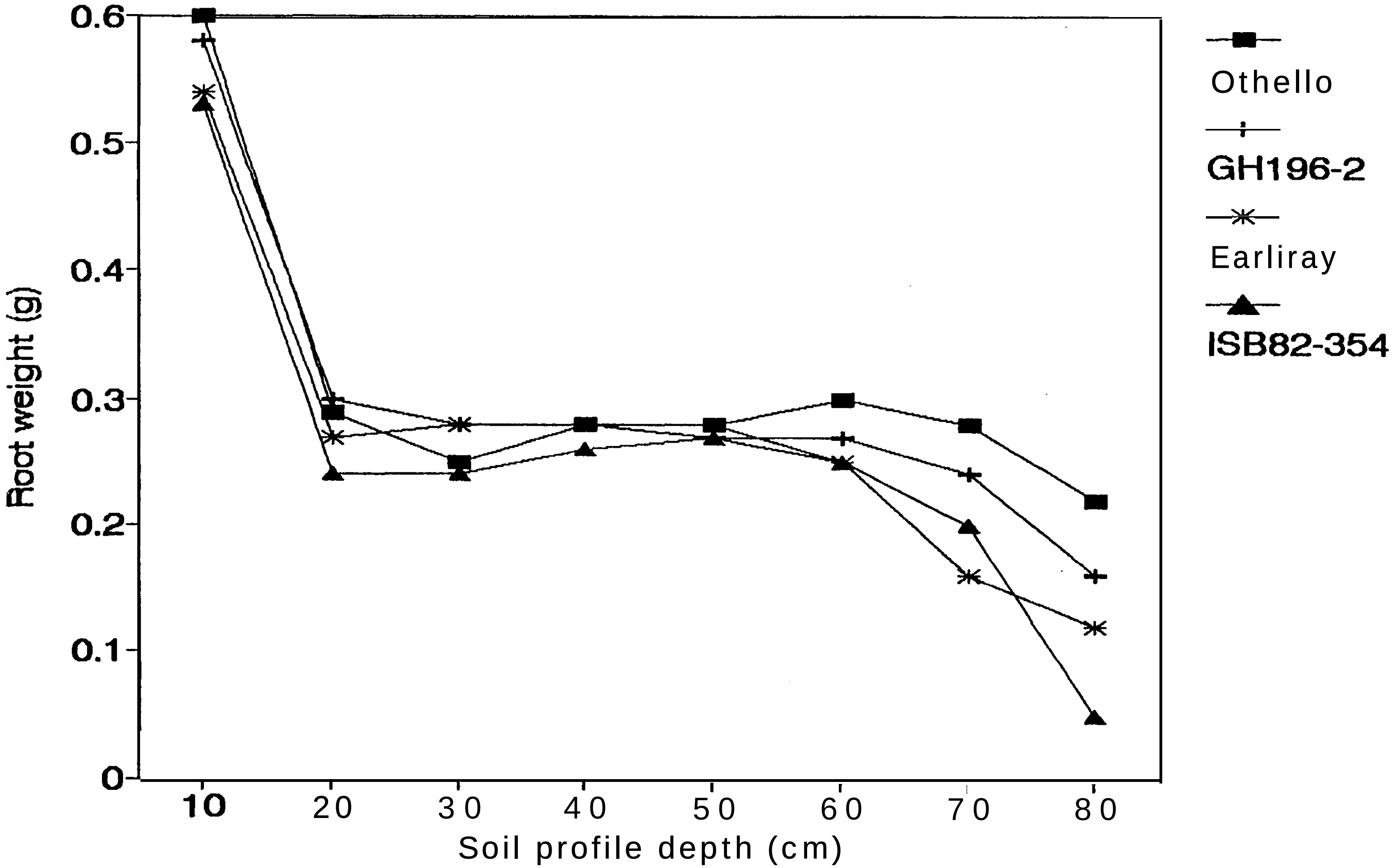

Fig 2 - Distribution of root weight in the soil profile for four selected bean genotypes, 1994. Data are averaged over the R6 and R8 stages of plant development.

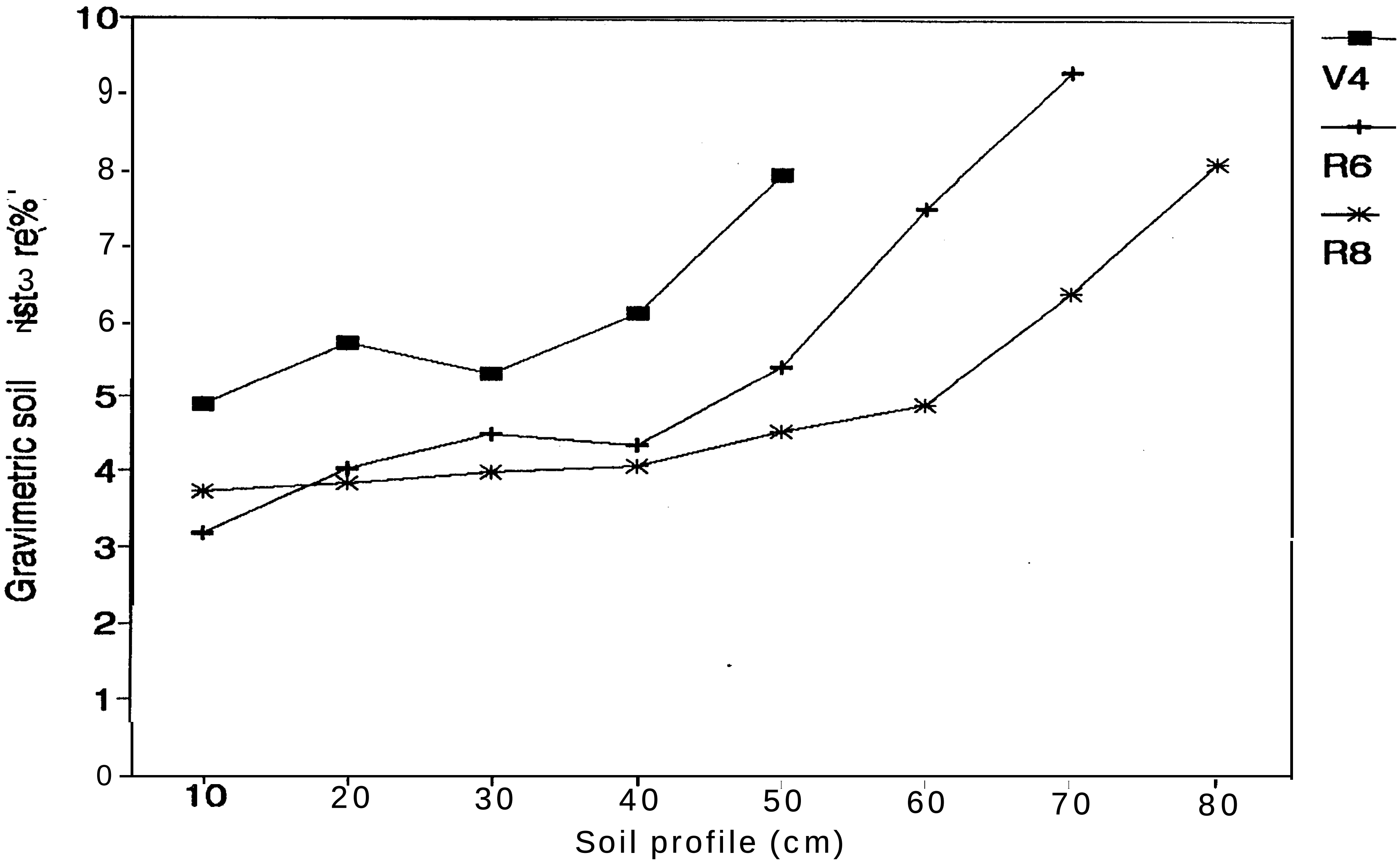

Fig 3 - Distribution of soil moisture in the soil profile at the V4, R6 and R8 stages of bean plant development, 1994 (average of 10 genotypes).