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Effect of moisture stress on biomass yield of soybean (*Glycine max*) in Nagpur district, Maharashtra

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Abstract

The fluctuation and decline in yield of soybean in Nagpur district is often attributed to variation in rainfall and occurrence of different degree of moisture stress. The experimental data of pot culture during two seasons indicated that a stress for 7 days during the period of seedling establishment resulted in yield loss upto 4.6 to 8.0 per cent and 5.9 to 18.4 per cent at grand growth stage. A maximum of 52.8 to 53.9 per cent loss in biomass was observed due to stress at pod formation and grain filling stages, respectively suggesting that for optimum soybean yield, the sowing date could be adjusted so that the critical stages like pod formation and seed development coincide with assured rainfall period preferably in the last week of August to first week of September.

Additional key words : Crop growth stages, weekly rainfall

Introduction

Soybean (*Glycine max* L.) in India was cultivated in about 5.8 million ha in 1997 from a meagre acreage of 0.03 million in 1970 (Damodaran and Hegde 1999). Soybean an important oilseed crop has been popularised especially amongst the farmers of Vidarbha region of Maharashtra due to its manifold benefits (Quayum *et al.* 1985). In Vidarbha, presently the area of traditional crops has been largely replaced by the advent of rainfed soybean. Although, soybean is grown under rainfall ranging from 800 to 1200 mm in almost all types of soils, the productivity fluctuates temporally mainly due to number and duration of dry spells (moisture stress) that prevail during the critical growth stages (Pawar *et al.* 1997; Lahiri 1978).

The peak water demand for soybean occurs during flowering to early pod filling stages and any stress at this stage leads to significant biomass reduction. Nasser *et al.* (1977) observed that the weight of seeds got reduced due to stress at flowering and early pod filling stages. Although shrink-swell soils have a capacity to store high amount of moisture, its relative availability is very low due to large amount of micro pores. Poor infiltrability of rainwater during rainy season also cause moisture stress to growing plants during lull period of rainfall in these soils. It has been reported that even a stress of 7 days period was sufficient for biomass reduction (Hajare 1999). The effect of water stress on yield in black soils of Vidarbha and particularly in Nagpur region under semi-arid to dry subhumid condition has not been studied earlier. Therefore, the present study was undertaken with the objective of quantifying the moisture stress vis-à-vis yield reduction for rainfed soybean in Nagpur district.

Materials and methods

The pot experiments were conducted at NBSS&LUP campus, Nagpur during *kharif* 1994 and 1995. The earthen pots of 45 cm diameter and 50 cm deep were filled up with dry soil having pH 8.2, clay 55%, $CaC0_3$ 15% and AWC 17.5% (collected from a pedon classified as fine, smectitic, hyperthermic Typic Haplusterts) upto a depth of 40 cm at an approximate bulk density of 1.5 Mgm^{-3} and with the provision of drainage at bottom. The recommended dose of NPK (20:60:20 $kgha^{-1}$) was mixed with soil. Two pots were kept for each treatment. One was kept at moisture stress and in the other pot, the crop was allowed to grow in natural environment (control plot) so that comparison can be made at each stage. Soybean cv.JS-8021 was sown in the last week of June in both the years. A moisture stress of 7 days period was allowed at each growing stage starting from 16 DAS (seedling stage) to 95 DAS (physiological maturity) by keeping the pot under polythene covered shed with adequate ventilation. However, for the rest of the period they were kept outside like control pots. The biomass was recorded at every stage for normal plant (control) as well as for plant under stress.

Results and discussion

The effective rainfall was 767.6 and 667.9 mm in 1994 and 1995, respectively but biomass (grain+straw) production at harvest in control plants (unstressed throughout the growing period) was 5.8 g/plant in 1995 and 5.4 g/plant in 1994.The higher biomass during 1995 was attributed to relatively uniform distribution of effective rainfall. The imposition of 7 days stress at seedling stage resulted in the reduction of biomass yield to the tune of 13.3 per cent in 1994 and 15.8 per cent in 1995. Further, data (Tables 1 and 2) indicated that biomass yields of unstressed plants which were more dependent on rainfall distribution rather than total/effective rainfall had 1.4 g/plant and 1.5 g/plant biomass in 1994 and 1995 respectively. The computation of data regarding final loss of biomass (at harvest) due to stress was found to be 4.6 per cent in 1994 and 8.0 per cent in 1995.

Table 1. Effect of moisture stress on biomass yield of soybean (1994)

Growth stages	Rainfall during growth period (mm)	Biomass before stress (g/plant)	Biomass after stress (g/plant)	Loss in biomass due to stress (%)	Biomass without stress (g/plant)	Biomass of stressed plant at harvest (g/plant)	Final loss of biomass (%)
Seedling	88.0	0.7	0.6	13.3	1.4	5.2	4.6
Vegetative							
Trifoliate	47.4	1.4	0.9	37.9	2.1	5.1	5.9
Four nodes	46.0	2.1	1.2	40.5	2.6	4.7	13.9
Six nodes	228.2	2.6	1.4	46.1	2.9	4.4	18.4
Flowering							
Beginning of bloom	226.0	4.1	1.8	56.6	4.4	4.2	23.2
Full bloom	-	4.4	2.3	48.3	5.9	4.1	24.3
Pod formation	-	5.9	2.7	53.9	6.2	3.7	31.9
Grain filling	73.0	6.2	2.9	52.8	6.5	3.7	32.4
Physiological maturity	59.0	6.5	3.4	47.5	6.6	4.7	13.2

Biomass production of unstressed plant was 5.4 g/plant at harvest.

At vegetative growth, it was noticed that there was linear increase in biomass in plants before and after stress and unstressed plant over seedling stage. A stress of 7 days at trifoliate, four and six node stages resulted in reduction of biomass to the tune of 33.2 to 46.1 per cent. However, at the harvest the loss of biomass of stressed plants *versus* unstressed plants at different grand growth stages, increased as plants advanced in their age. The critical analysis of data indicated that final loss in biomass of stressed plants over unstressed plants varied from 5.9 to 18.4 per cent in 1994 and 9.5 to 18.2 per cent in 1995 at grand growth stage. This suggests that soybean plant has the capacity to compensate the biomass loss in early growth stages through gaining of biomass at later stages.

The data collected at the beginning of bloom and full bloom indicate that stress-induced biomass reduction has further widened as compared to grand growth stage in both the years. The final loss in biomass was 23.2 to 24.3 per cent in 1994 and 26.4 to 29.9 per cent in 1995. It clearly demonstrated that per cent reduction in biomass went on continuously increasing because soybean can tolerate stress environment prior to flowering but adequate moisture is essential during pod formation and grain filling stress.

Table 2. Effect of moisture stress on biomass yield of soybean (1995)

Growth stages	Rainfall during period (mm)	Biomass before stress (g/plant)	Biomass after stress (g/plant)	Loss in biomass due to stress (%)	Biomass without stress (g/plant)	Biomass of stressed plant at harvest (g/plant)	Final loss of biomass (%)
Seedling	188.3	0.8	0.7	15.8	1.5	5.4	8.0
Vegetative							
Trifoliate	51.2	1.5	1.0	33.2	2.3	5.3	9.5
Four nodes	7.4	2.3	1.4	38.8	2.9	4.9	16.2
Six nodes	53.2	2.9	1.7	41.5	3.1	4.8	18.2
Flowering							
Beginning of bloom	11.6	4.4	2.1	53.5	4.8	4.3	26.4
Full bloom	270.1	4.8	2.4	50.0	6.2	4.1	29.9
Pod formation	15.4	6.2	3.2	48.8	6.4	3.8	35.6
Grain filling	43.5	6.4	3.3	48.5	6.6	3.5	40.0
Physiological maturity	32.2	6.6	3.8	47.6	6.9	5.3	10.4

Biomass production of unstressed plant were 5.8 g/plant at harvest.

The stress induced loss of biomass at pod formation and grain filling stages ranged from 52.8 to 53.9 per cent in 1994 and 48.5 to 48.8 per cent in 1995. However, computation of data on final loss in biomass of stressed plants indicated that magnitude of loss further enhanced as compared to flowering stage although biomass production was higher. This may be due to unavailability of water for translocation of carbohydrates and protein synthesis in seed formation. It was further confirmed by the rapid yellowing and falling of leaves. It was also observed that at physiological maturity, stress reduced the biomass yield to the tune of 47.5 to 47.6 per cent in 1994 and 1995, respectively and corresponding values for final loss in biomass was 13.2 per cent in 1994 and 10.4 per cent in 1995. This indicated that moisture stress at physiological maturity did not affect photosynthates significantly.

The results presented in tables 1 and 2 suggested that loss of biomass was higher during 1994 coinciding with erratic distribution of rains during the growth cycle of the soybean crop (Table 3). The well distribution of rains influenced the soil moisture storage leading to better crop growth and biomass yield during 1995. Similar observation was also recorded by Kanwade *et al.* (1990). The soybean has indeterminate type of growth habit, and the flowering period can be of 25 days starting from 40 to 65 days for different genotypes followed by pod formation and grain filling which have peak water demands and any stress during this period leads to heavy reduction in biomass (Nasser *et al.* 1977). The adequate amount of water and its proper distribution especially during critical stages of crop development improved the yield attributes (Virmani *et al.* 1989). In Nagpur district mostly this period coincides with the second fortnight of September which is the period when rainfall almost ceases resulting in varying degree of crop stress and considerable yield reduction over the years. The rainfall data presented in table 3 also supports the fact because it is generally accepted that continuous two week rainfall of 30 mm in each week or a total of 75 mm rainfall in two weeks is suitable for sowing of rainfed crop in the central India (Ramkrishna *et al.* 2000).

Thus it may be concluded that soybean crop suffers most at stress during the pod formation and grain filling stage for which the yield loss could be on an average of 47 to 50 per cent. Therefore, the growing period could be manipulated to avoid the stress period. In Nagpur more assured rainfall is obtained during last week of August to first 10 days of September (Table 3). Considering the 120 to 130 days length of growing period of soybean, the optimum sowing period should be the last week of June and the first week of July.

Table 3. Rainfall distribution pattern for critical weeks and soybean yield (mean) for Nagpur district

Year/ Met week		1994	1995
22	28-3 June	–	–
23	4-10 June	23.0	–
24	11-17 June	50.0	1.2
25	18-24 June	61.0	66.4
34	20.26 August	46.0	11.6
35	27-2 September	228.2	270.7
36	3-9 September	226.0	15.4
37	10-16 September	–	43.5
38	17-23 September	–	32.2
Soybean yield kg/ha (mean)		1232	789

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