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Research Article

Evaluation of soybean cultivars and lines under excessive moisture stress in Eastern Madhya Pradesh

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ABSTRACT

In India, soybean is a rainy (*kharif*) season crop which faces excessive moisture stress (EMS) between seedling and flowering. This stress is remarkable especially in Madhya Pradesh (MP) state that accounts for 35% of national soybean production. Therefore, there is need to evaluate current popular cultivars and advanced lines under EMS conditions in MP. A field evaluation was conducted at Jawaharlal Nehru Agricultural University in Jabalpur, MP. A total of 25 soybean cultivars and lines were exposed to EMS condition at 15-20 DAS, 35-40 DAS and 55-60 DAS. As the control, the same set of soybean genotypes was grown in a well drained field condition with general cultivation practices. The EM condition resulted in drastic reduction in nodule numbers, fresh weight and dry weights at flowering, but no change in number of branches per plant, days to 50% of flowering and days of maturity. However, for some cultivars, e.g. NRC-37, highest dry weight was recorded in EMS condition. At harvest, number of seeds per plant, hundred seed weight, grain yield and harvest index decreased with EMS, relative to the control. In the control condition, the high yielding popular cultivars were Bragg (2759 kg ha^{-1}), JS 97-52 (2407 kg ha^{-1}), and NRC-37 (2398 kg ha^{-1}), JS 335 (1305 kg ha^{-1}) and JS 95-60 (1222 kg ha^{-1}). Slightly higher yield per hectare was observed for advanced lines in control as follows: JS 20-71, 3120 kg; JS 20-87, 2991 kg; RVS2001-4, 2602 kg; JS 20-50, 2583 kg. The consistently lower yields in EMS condition over lines and cultivars suggest that a further effort to expand screening of genotypes is required for genetic improvement of EM stress tolerance.

Keywords: Excessive moisture stress (EMS) soybean, DAS (days after sowing)

INTRODUCTION

Soybean has been adapted and commercially cultivated in Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh. At present, it has been established as a most important oilseed crop of India in general and Madhya Pradesh in particular. Soybean (*Glycine max* (L.) Merrill) ranks first among the oil seed crops in the India as well as in the world.

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Soybean has unprecedented expansion in India by recording 15-20% annual growth rate. It has emerged very fast since early eighty's and occupied vital place in agriculture, edible oil economy, foreign exchange and enlistment of soybean farmers. It contributes around 25% of total edible oil pool of the country.

In India, in the year 2011-12, soybean cultivation reached 103 lakh hectares recording production of 119 lakh tonnes with an average of 1155 kg/ha. In Madhya Pradesh in the year 2011-12, area production and productivity was

57.0 lakh hectare, 62 lakh tonnes, 1077 kg/ha respectively. The present yield level is quite low in comparison to world's average i.e. 22 q/ha. Among the major constraints, the erratic monsoon and climate change adversely affect the productivity. The soybean is covering vast area representing varied eco-edaphic conditions. Plants are subjected to a range of abiotic stresses that affect the growth and development adversely. Being a rainfed crop, soybean faces unpredictable moisture stresses either excess or scarce.

Soybean is a *kharif* crop and planting time is from mid June to mid July but due to climate change unpredicted rainfall occurs sooner or later. Either heavy rainfall damages crop at seedling stage or late rainfall creates water deficit (drought) at flowering and pod filling stages of soybean. Occasional exposure to both the types of stresses during same crop cycle, i.e. excess moisture at seedling, vegetative stage and drought during flowering and pod filling stage is common. Therefore, there is need of development of tolerant soybean genotypes for excess moisture stress and water deficit (drought) conditions.

Soybean is very sensitive to excess water as compared to other crops. Soybeans can survive underwater for a week or more under ideal conditions. Generally, soybeans tolerate 48 hours under water quite well but flooding for 4 to 6 days can reduce stands, vigour and eventually seed yield (Scott et al., 1989). Water logging tolerance was assessed in cultivars at early vegetative stages and early reproductive stages and results indicate the most susceptibility to excess water at the growth stages. Physiological characters including leaf water use efficiency were promising indicators for screening soybean which is tolerant to excess water conditions (Lee et al., 2004).

Although all higher plants require access to free water, excess water in the root environment of land plants can be injurious or even lethal because it blocks the transfer of oxygen and other gases between the soil and the atmosphere. Crop plants require a free exchange of atmospheric gases for photosynthesis and respiration; plants can be easily suffocated if this gas exchange is impeded. Oxygen status of cells and tissues varies significantly during ontogenesis and depends on environmental oxygen supply. The most common impediment to gas diffusion is water that saturates the root environment in poorly drained soils or that accumulates above soil capacity as a result of the overflow of rivers, excessive rainfall or excessive irrigation (Sairam et al., 2008). Growth is greatly inhibited in the deficiency (hypoxia) or complete absence (anoxia) of oxygen. In water-saturated soils roots grow only in a small region near the surface and do not exploit a large soil volume as they would under aerated conditions. Plants invariably wilt within few hours to 2-4 days of imposing a flooding stress (Jackson & Drew, 1984). Water logging to 8 days caused significant increase in O_2^- and H_2O_2 contents, and the values were 80–90% of the control values more. Gene expression studies showed enhanced expression of cytosolic-Cu/Zn-superoxide dismutase (SOD) and cytosolic-ascorbate peroxidase (APX) in the roots of waterlogged (Sairam et al., 2011). Water logging is also known to induce adverse effects on several physiological and biochemical processes of plants by creating deficiency of essential nutrients like nitrogen, magnesium, potassium, calcium. Apart from these Water logging induced alterations in physiological mechanisms, plants growing under flooded conditions also exhibit certain morphological changes entailing the formation of adventitious roots, initiation of hypertrophied lenticels and/or establishment of aerenchyma (Muhammad, 2012).

Water logging resulted in decrease in relative water content (RWC), membrane stability index (MSI) in root and leaf tissues, and chlorophyll (Chl) content in leaves, while the Chl a/b ratio increased (Sairam et al., 2009). Although water logging caused decline in total, non-reducing sugars and activity of alcohol dehydrogenase (ADH) increased up to 8 days of water logging (Sairam et al., 2009). Water logging tolerant genotypes depend on the availability of sufficient sugar reserve in the roots, activity of sucrose synthase to provide reducing sugars for glycolytic activity and ADH for the recycling of NADH for the continuation of glycolysis, the major source of energy under hypoxia. This was reflected in better RWC and Chl content in leaves, and membrane stability of leaf and root tissue (Kumutha et al., 2008). Soybean dry matter and nitrogen were determined at various times following the initiation of flood or low O_2 treatment. N_2 fixation was more sensitive to flooding than was biomass accumulation. The decrease in N_2 fixation occurred faster (within 7 days of flooding) than decrease in biomass (within 14-21 days) and the decrease in N_2 fixation was more pronounced than the decrease in biomass (Bacanamwo & Purcell, 1999). According to Turner et al. (2013), there is very low auxin activity during soybean nodule initiation, hypersensitivity to auxin inhibits nodule development and a regulatory feedback loop involving auxin and cytokinin is crucial for proper nodule development in soybean. Soybean management system influenced development of the different yield components and produced seed mass ranging from 10.5 to 16.5 g 100 seed^{-1}, seed number from 2878 to 3824 seeds m^{-2}, pod number from 1182 to 1571 pods m^{-2}, seeds per pod from 2.36 to 2.49 seeds pod^{-1}. Harvest index ranged from 56.2-58.0% across management systems as reported by Pedersen & Lauer (2004).

MATERIALS AND METHODS

The experiments were conducted at the Department of Plant Breeding and Genetics, Jawaharlal Nehru Agricultural University in Jabalpur, MP in collaboration with Japan International Cooperation Agency (JICA), College of Agriculture Indore, Indore, MP. The plot size of each genotype was 3.6 m^2 (2m x 1.8m). There were four rows in each plot; row to row spacing was 45cm and plant to plant spacing 6.25 cm. Plant population of 128 plants per plot was maintained.

Thirty two plants were maintained in each row (2 meter). The statistical analysis was done using Factorial Randomized Block Design (FRBD) with three replications. Sowing was completed on 6th July 2012. A total of 25 soybean cultivars and lines were exposed to EMS condition at 15-20 DAS, 35-40 DAS and 55-60 DAS (Seedling, vegetative, reproductive and pod filling stage). As the control, the same set of soybean genotypes were grown in a well drained field condition with general cultivation practices. Soil moisture percentage was calculated at 30 DAS, 60 DAS and 90 DAS (Black, 1965). Metrological Observations were collected from Agro-metrological Department JNKVV-Jabalpur (M.P.) (Table 1 and Plate 1-4).

Table 1: List of twenty five soybean genotypes

Eastern New Genotypes JNKVV-Jabalpur	**Western New Genotypes RSKVV, (Sehore) Gwalior**	**Popular Varieties**
1. JS20-50	11. RVS2001-4	19. JS95-60
2. JS20-53	12. RVS2007-1	20. JS 93-05
3. JS20-59	13. RVS2007-2	21. JS 335
4. JS20-69	14. RVS2007-3	22. JS 97-52
5. JS20-71	15. RVS2007-4	23. Bragg
6. JS20-73	16. RVS2007-5	24. NRC-37
7. JS20-79	17. RVS2007-6	25. NRC-7
8. JS20-80	18. RVS2007-7	
9. JS20-86		
10. JS20-87		

Evaluation of soybean tolerant genotypes on the basis of observations

Morphological and phenological

Plant population at 20 DAS, flowering, and maturity, number of branches/plant at maturity, days to 50% flowering, days to maturity, dry matter accumulation at maturity was recorded.

Full bloom (nodule observation)

Number of nodes per plant, nodules fresh weight and dry weight (g) per plant were recorded as suggested by Barbedo (2012).

Plate 1: Emergence of soybean genotypes overview under Control (Non-flooded).

Plate 2: Excessive Moisture Stress (EMS) (Flooded 7 days water stagnation).

Plate 3: Maintained plant population, nodule counting and soil collection in two environments.

Plate 4: Nodule formation under control and excessive moisture stress conditions.

Yield and yield components

Number of pods per plant, number of seed per plant, biological yield per plot, hundred seed weight (test weight), grain yield per plant and grain yield per plot, harvest index (%) as suggested by Pedersen & Lauer (2004).

RESULTS AND DISCUSSION

Morphological and phenological

A total of 25 soybean cultivars and lines were maintained, plant population at initial 20 DAS seedling stage was recorded (Figure 1). The maximum plant population loss for genotypes exposed to water stagnation or flood (7 days) was recorded at 16.36% flowering stage (Fig. 2).

Metrological observations on rainfall, temperature and relative humidity from July to October 2012 were recorded. Soil moisture percentage was recorded at 30 DAS, 60 DAS and 90 DAS. The soil moisture was increased 10.6% at 30DAS. However, at 60 DAS and 90 DAS soil moisture was increased by 2.3% and 3.7% under excessive moisture compared to control (Figure 3 and 3a).

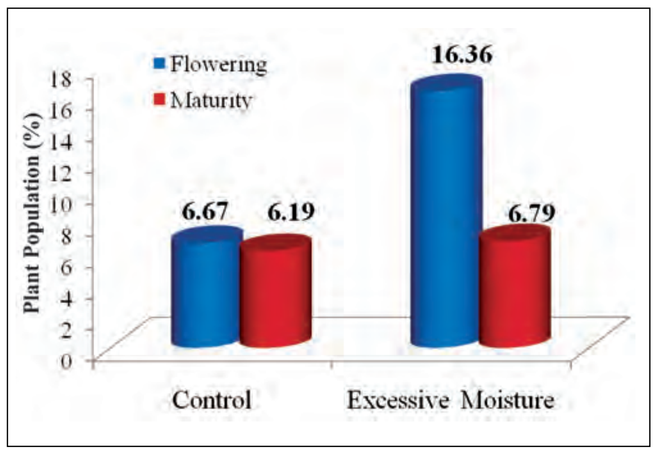


Figure 2: Loss of plant population under excessive moisture stress at flowering and maturity stage

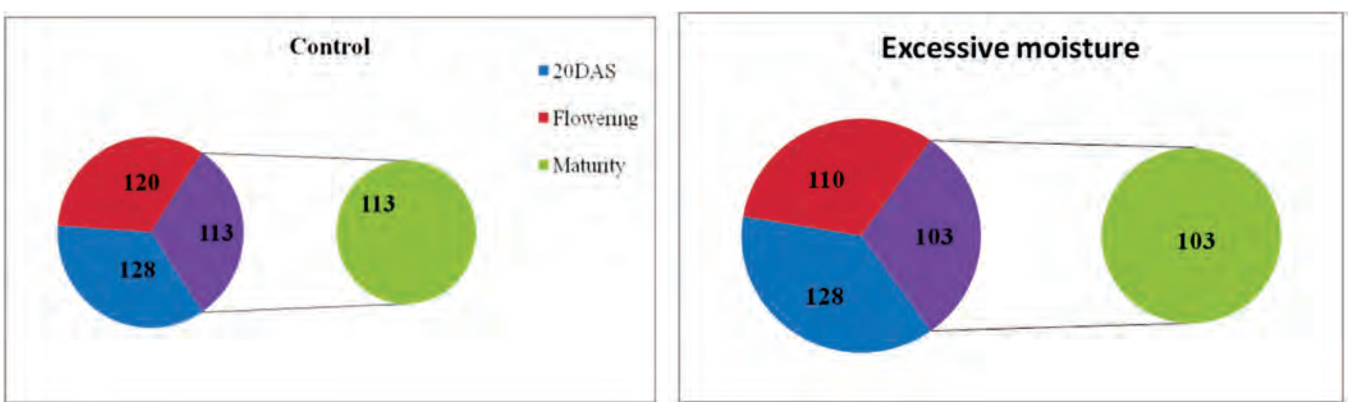


Figure 1: Plant population mean value of 25 soybean cultivars and lines at 20DAS, Flowering and Maturity stages

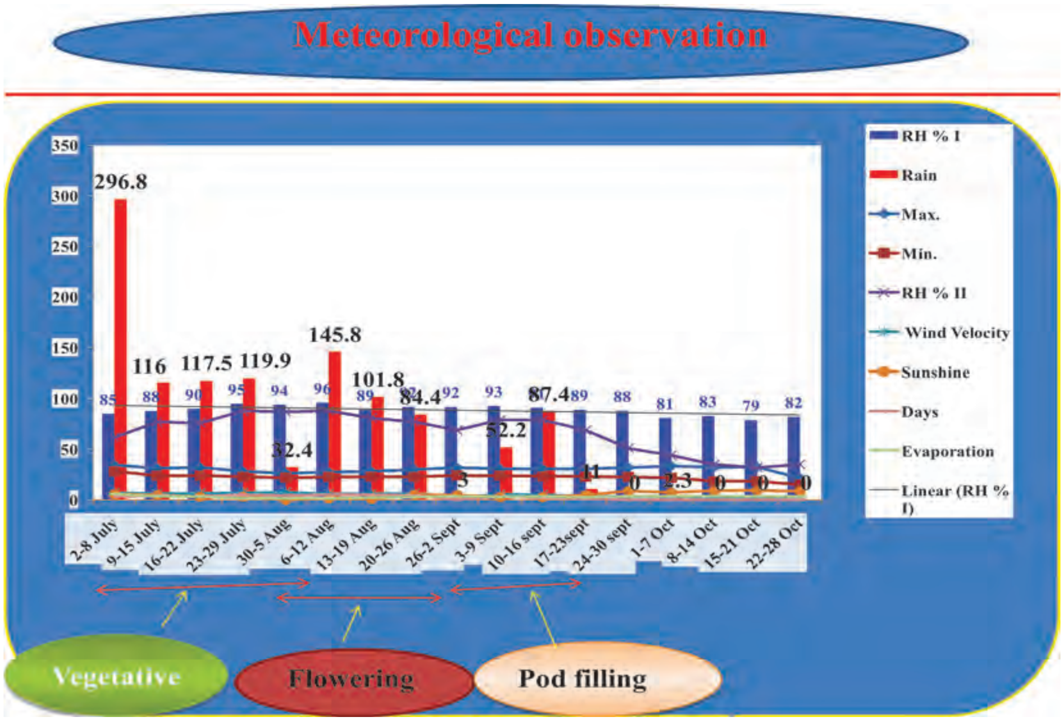


Figure 3: Meterological observations from July-October, 2012

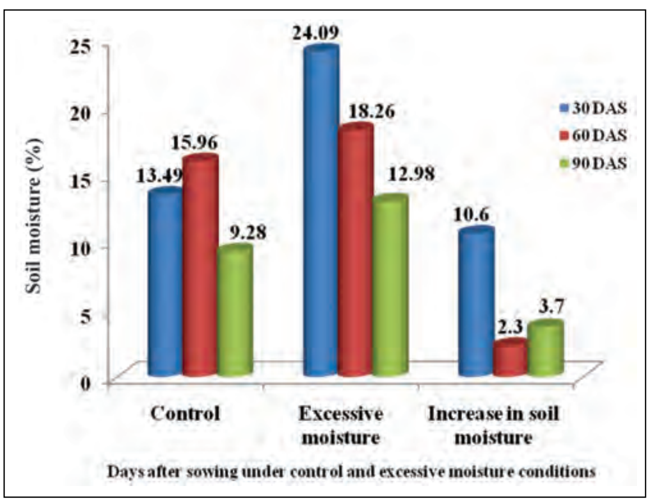


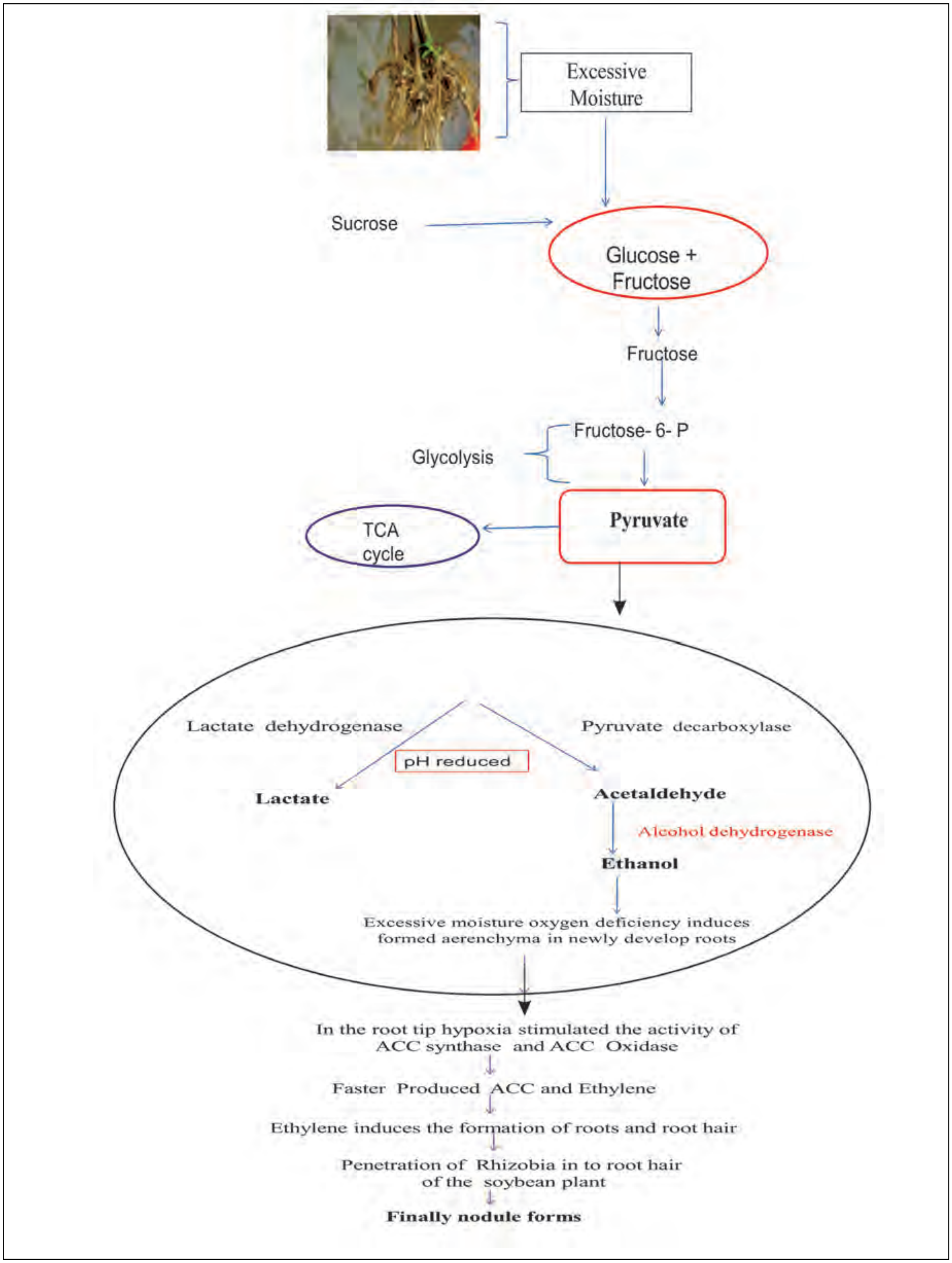
Figure 3a: Soil moisture percentage illustrated under control and excessive moisture condations

Full bloom (nodule observation)

Number of nodule, nodule fresh weight and dry weight was recorded at full bloom stage of soybean genotypes. Number of nodule, nodule fresh weight and dry weight were decreased significantly in excessive moisture stress compared to control (Figure 4). Excessive moisture stress, root respiration rate and metabolism are affected even before O_2 is completely depleted from root environment generated anoxic or hypoxic conditions. Thus injury to root metabolism by O_2 deficiency originates in part from a lack of ATP to drive essential metabolic processes (Drew, 1997). Soybean tolerant genotype had exposure of 7 days after flood. Tolerant genotypes change rooting formation behavior of adventitious roots and form aerenchyma tissue in the presence of alcohol dehydrogenase enzyme produced ethanol. Alcohol dehydrogenase (Adh) is the key enzyme in alcohol fermentation. We analyzed Adh expression in order to clarify the role of Adh of soybeans (*Glycine max*) to flooding stress. Proteome analysis confirmed that expression of Adh is significantly upregulated in 4 days old soybean seedlings subjected to 2 days of flooding (Komatsu et al., 2011).

Popular cultivar NRC-37 showed enhanced dry matter accumulation under excessive moisture. However

Line diagram representing the mechanism of nodule formation in tolerant soybean genotypes beneath excessive moisture condition



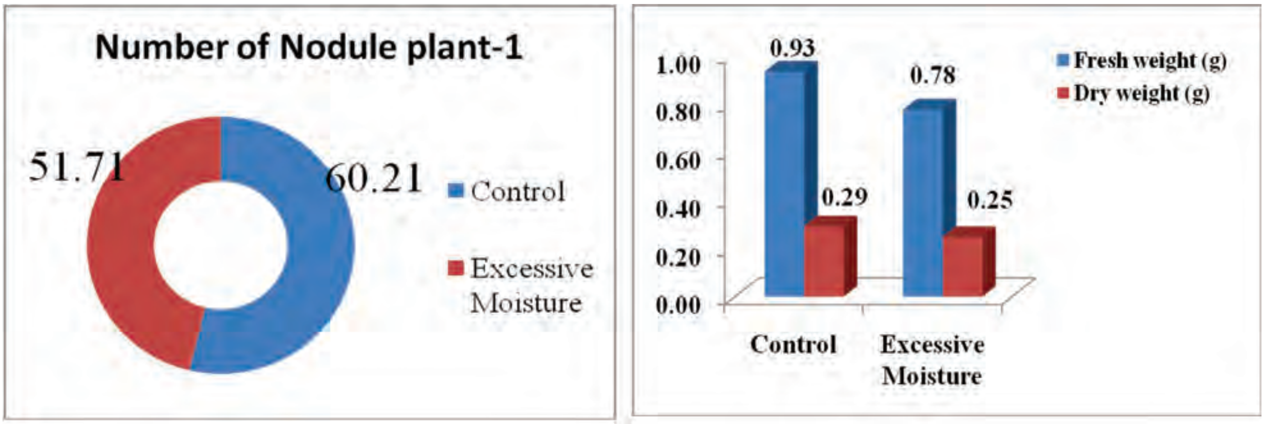


Figure 4: On the basis of mean 25 genotypes represent number of nodule, nodule fresh weight and nodule dry weight per plant under control and excessive moisture

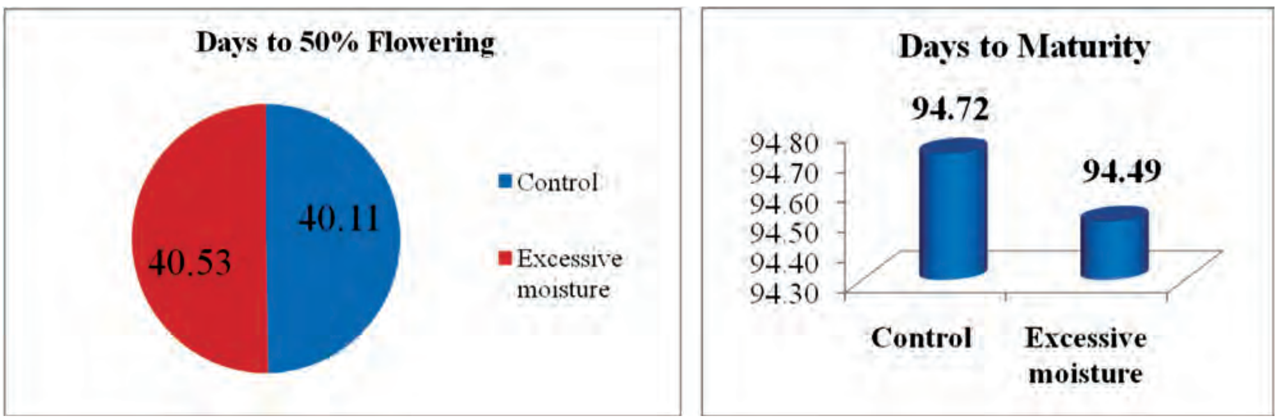
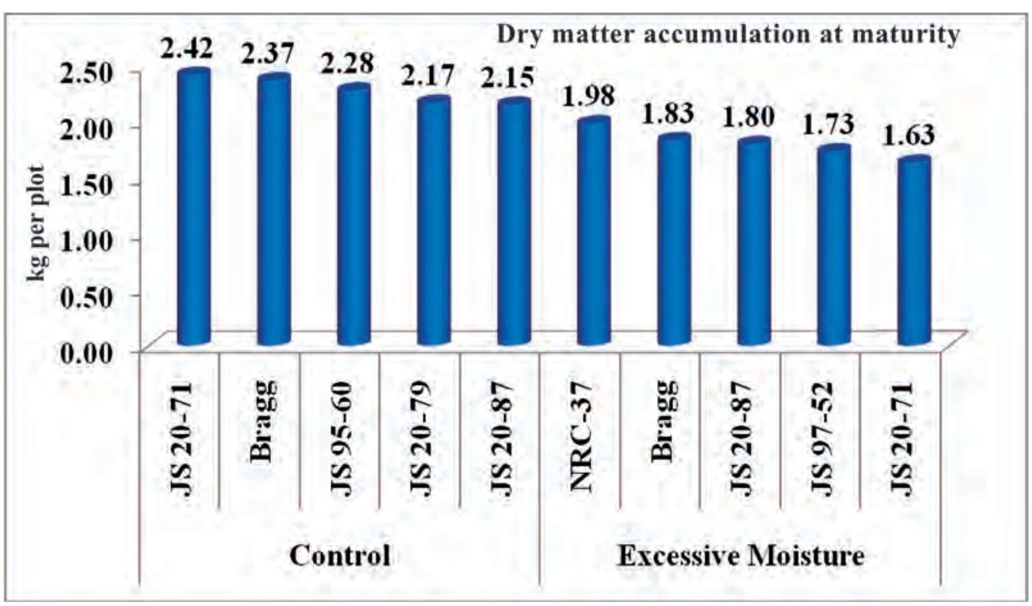


Figure 5: On the mean basis soybean genotypes illustrated, days to 50% flowering and days to maturity under control and excessive moisture condition

Figure 6: A total of 25 soybean cultivars and lines out of which five genotypes showed highest dry matter accumulation under control and excessive moisture conditions



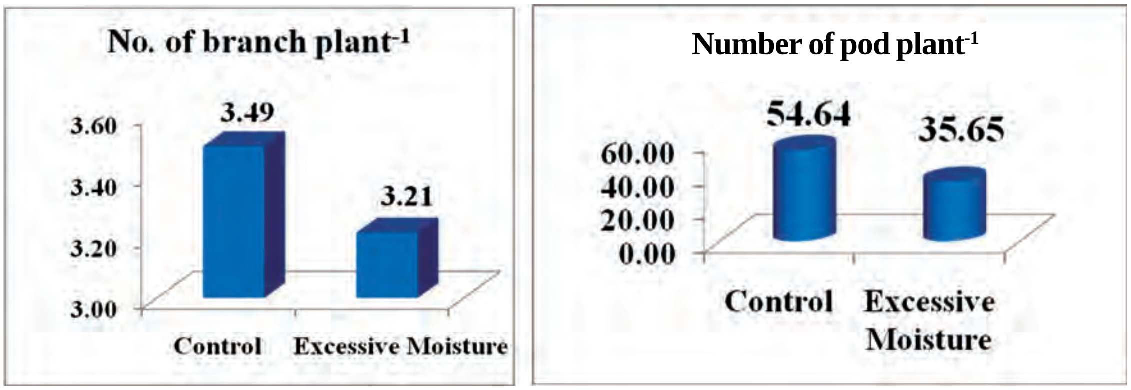


Figure 7: Number of branches and number of pod per plant under control and excessive moisture stress

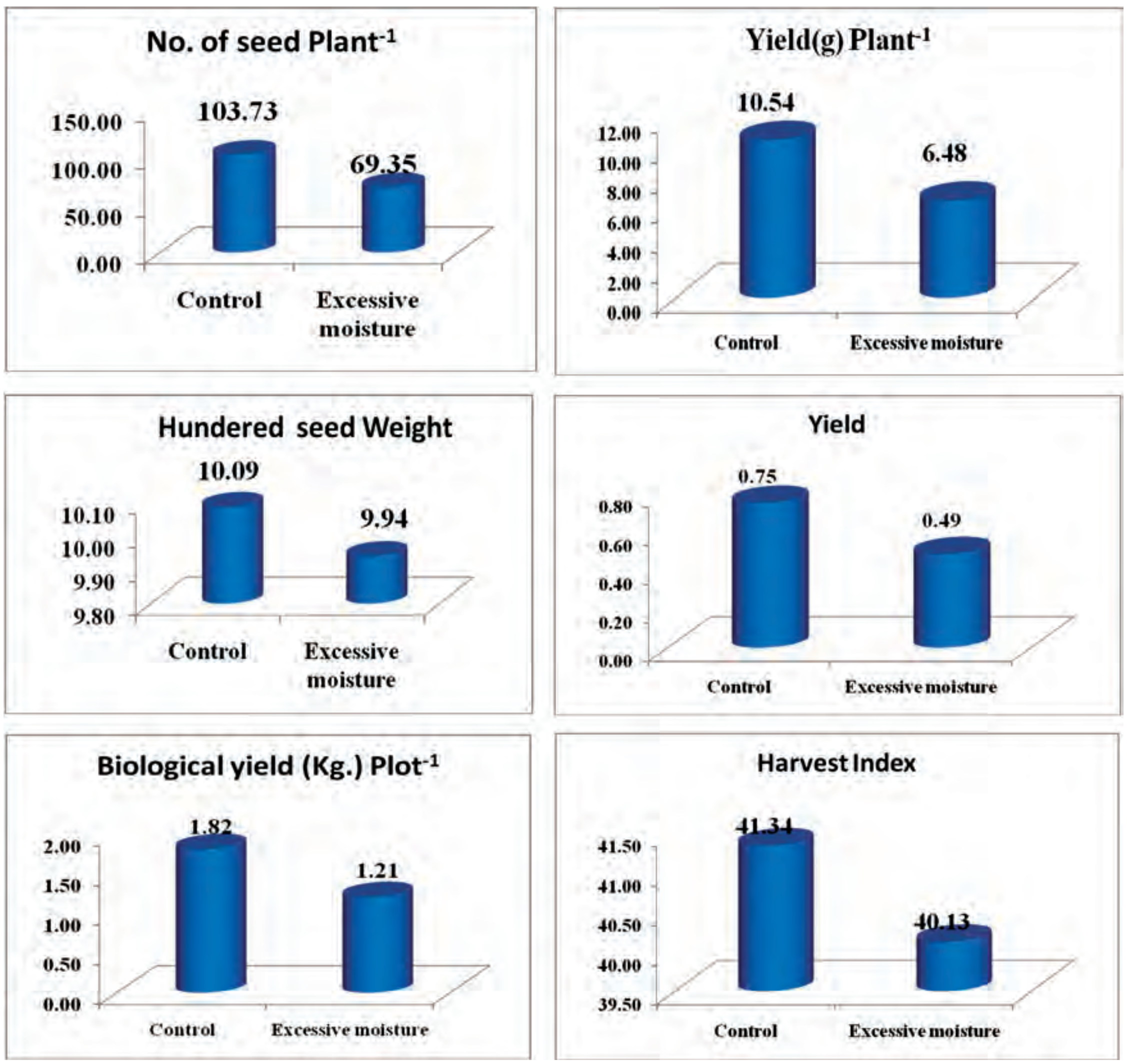


Figure 8: Grain yield per plant, number of seed per plant, hundred seed weight and grain yield per plot, biological yield per plot and harvest index (HI %) represent mean value of 25 soybean genotypes under control as well as excessive moisture

advance line JS 20-71 showed higher dry matter accumulation under control condition. The flood induced N deficiency may be the cause of the decreased biomass accumulation. Wilson (1988) suggested that for any limiting resource, availability within the plant decreases with distance from the site of uptake. This implies that under nutrient deficits, shoots are more starved than roots and this could decrease photosynthesis and the overall dry matter accumulation.

Yield and yield components

Number of branches per plant at maturity was similar under control as well as excessive moisture stress. However number of pods per plant was significantly decreased (Figure 7) At Days to 50% flowering, 50% soybean plants showed bearing of atleast one flower. At Days to maturity above 50%, pod colour was changed to yellow and dry matter accumulation came to an end

Table 2: A total of 25 soybean cultivars and lines yield kg ha^{-1} under control and excessive moisture condition

S.No.	Control	kg ha^{-1}	Excessive Moisture	kg ha^{-1}
1	JS 20-71	3120.37	JS 20-87	2055.56
2	JS 20-87	2990.74	JS 20-71	1935.19
3	JS 20-79	2759.26	Bragg	1935.19
4	Bragg	2759.26	JS 97-52	1861.11
5	RVS 2001-4	2601.85	RVS 2001-4	1861.11
6	JS 20-50	2583.33	JS 20-50	1833.33
7	JS 20-73	2425.93	NRC-37	1648.15
8	JS 97-52	2407.41	JS 20-59	1564.81
9	NRC-37	2398.15	JS 20-79	1546.30
10	RVS 2007-4	2287.04	JS 20-53	1509.26
11	JS20-69	2231.48	RVS 2007-1	1425.93
12	JS20-86	2212.96	JS 20-80	1425.93
13	RVS 2007-6	2157.41	JS20-69	1370.37
14	JS 20-53	2138.89	RVS 2007-6	1314.81
15	RVS 2007-1	2101.85	JS 20-86	1296.30
16	JS 20-59	1981.48	RVS 2007-4	1268.52
17	JS 20-80	1842.59	RVS 2007-3	1203.70
18	RVS 2007-2	1842.59	RVS 2007-2	1129.63
19	RVS 2007-3	1842.59	RVS 2007-7	1092.59
20	RVS 2007-7	1750.00	JS 335	990.74
21	JS 335	1305.56	JS 95-60	851.85
22	RVS 2007-5	1259.26	JS 93-05	814.81
23	JS 95-60	1222.22	JS 20-73	703.70
24	JS 93-05	1074.07	RVS 2007-5	620.37
25	NRC -7	833.33	NRC -7	453.70
	CD (5%)	612.60	CD (5%)	342.03
	S Em±	191.99	S Em±	107.20

(Figure 3). Current photosynthesis (rather than remobilization of stored carbohydrate) is considered to be the main source for seed growth in soybean (Liu et al., 2004).

Grain yield per plant, number of seed per plant, hundred seed weight and Grain yield per plot, biological yield per plot and harvest index (HI) were decreased significantly under excessive moisture condition. Pod number was more responsive to altered source strength than other yield components including seeds per pod and seed size (Mathew et al., 2000).

On the overall yield basis five popular released varieties and four new genotype were identified for significant yield responses under excessive moisture stress conditions (Table 2 and Figure 9a and b). Under the control condition, the highest yielding popular cultivars were Bragg (2759 kg ha^{-1}), JS 97-52 (2407 kg ha^{-1}), and

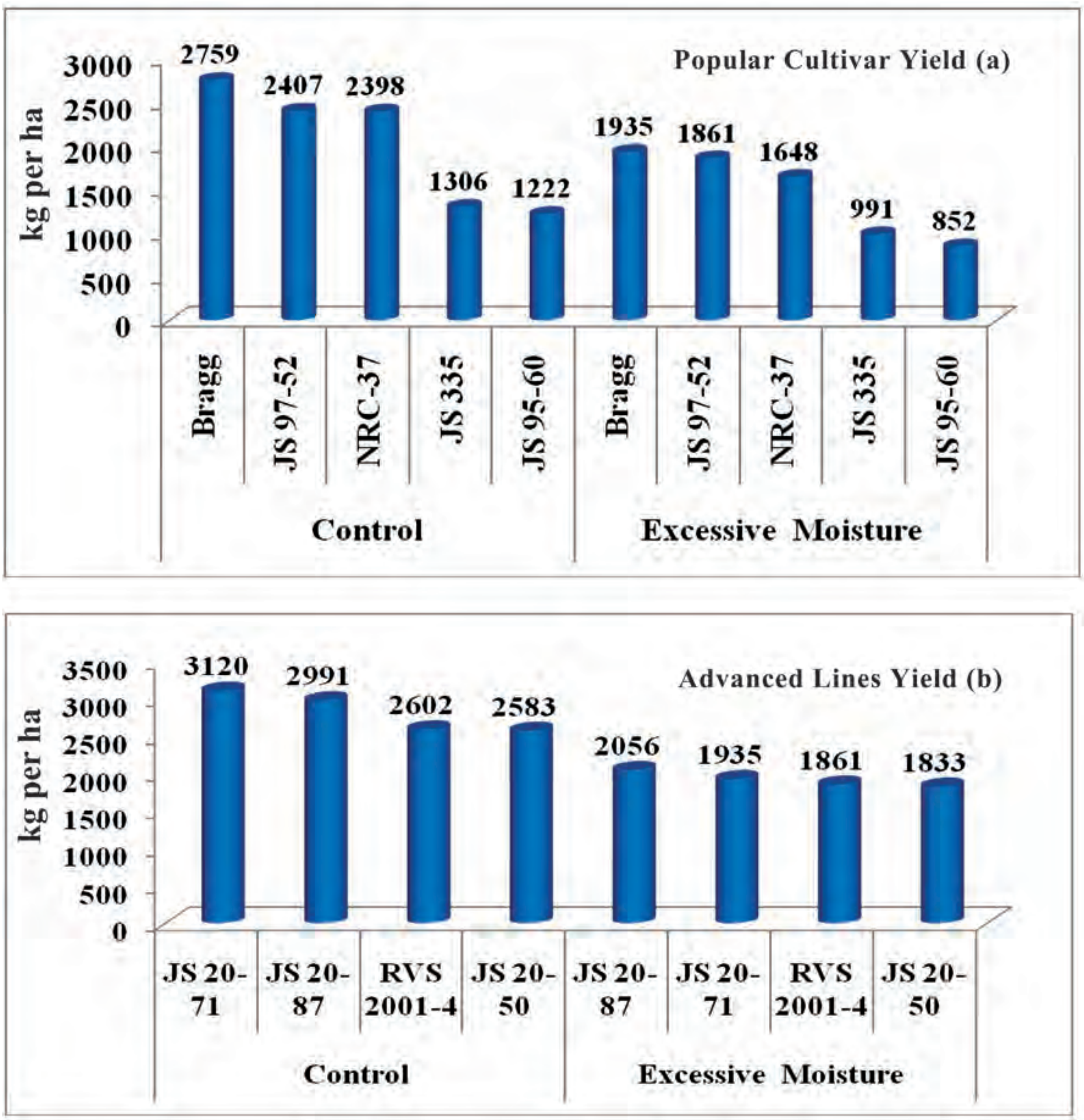


Figure 9: Yield performance of soybean genotypes illustrated (a) Popular cultivar and (b) Advanced lines under control and excessive moisture conditions

NRC-37 (2398 kg ha^{-1}), JS 335 (1305 kg ha^{-1}) and JS 95-60 (1222 kg ha^{-1}). Slightly higher yields per hectare were observed for advanced lines in control as follows: JS 20-71(3120 kg), JS20-87(2991 kg), RVS2001-4 (2602 kg), JS 20-50 (2583 kg) Advanced line having higher tolerance capacity and osmotic adjustment behaviour, proper sink source relation. New or modern cultivars were reported to have more dry matter production during seed filling period (Liu et al., 2005).

CONCLUSION

The present experiments illustrated evaluation of 25 soybean cultivars and lines grown under two conditions i.e. control (non-flooded) and Excessive moisture (flooded field). On the basis of yield performance evaluated soybean tolerant cultivars and lines. Excessive moisture, tolerant cultivars and lines produced more pods $plant^{-1}$, number of seeds $plant^{-1}$ and heavier seed weight and higher yield. On the basis of yield performance the popular cultivars and advanced lines Bragg, JS 97-52 and JS20-87, JS20-71 showed higher yield up to some extent, under excessive moisture stress as well as control condition respectively.

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