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Dry Matter Partitioning and Yield of Different Varieties of Soybean (*Glycine max* (L.) Merrill) under Aberrant Climatic Conditions in Central India

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Authors' contributions

This work was carried out in collaboration between all authors. Author SN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KR and SR managed the analyses of the study. Author JS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To study the effect of sowing dates on dry matter partitioning and yields of soybean cultivars field experiment was carried out at Indian Institute of Soil Science, Bhopal.
Materials and Methods: Ten varieties of soybean were raised in two sowing dates under rainfed conditions in black soil of central India. First sowing was done at optimum date (first week of July) and second 15 days after the first date.
Results: Results showed that sowing at optimum date recorded significantly higher pre-flowering DMP (7.65 g plant^{-1}), DMP at maturity (13.27 g plant^{-1}), percent of post flowering DM partitioning into seed (46.45 %), pod dry weight (5.02 g plant^{-1}), seed weight (2.67 g plant^{-1}) and HI (34%) compared to second sowing. Among the varieties JS 8021 recorded significantly higher pre flowering DMP (8.34 g plant^{-1}) followed by JS 9752 (7.7 g plant^{-1}), DM at maturity by JS 9752 (12.73 g plant^{-1}), pod weight (5.4 g plant^{-1}) and seed weight (3.19 g plant^{-1}) by JS 9560 followed by JS 9752 (4.1 g plant^{-1} and 2.15 g plant^{-1} respectively) and HI by JS 9560 (0.34).
Conclusion: It can be concluded that the variety JS 9752 may be taken up to minimize the yield loss due to delay in sowing.

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Keywords: Soybean; varieties; climate; dry matte production; yield.

1. INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) designated as 'miracle bean' is one of the most important oil seed crop in the world. Soybean is a member of the family Leguminoceae, subfamily Papilionoideae, grown for the seed which is one of the most important sources of protein and oil. In India soybean is traditionally grown in the *'Kharif'* or monsoon season as a rainfed crop and assumed as one of the most stable *kharif* pulses under diverse agro-climatic conditions [1]. Among the Indian states, Madhya Pradesh is known as the 'soybean belt' which alone accounts for 81% of the area under soybean cultivation.

Generally soybean is grown as a rainfed crop and the sowing is dependent on the onset of monsoon. This makes planting date a very important consideration in soybean.

Due to delayed monsoon or continuous rains sowing is sometimes not possible at the recommended sowing date particularly in central India. Delayed planting especially due to environmental factors such as very high temperature and drought stress will negatively affect growth and yield of the plant. It is reported that planting date is a key factor affecting soybean growth and development, grain yield [2], and grain quality [3]. Karmakar and Bhatnagar [4] reported that there may be 17-39% yield reduction due to delayed sowing. Also it has been reported that soybean yield is governed by the time of sowing and spatial arrangements in the field [5].

Most varieties of soybean are extremely sensitive to variations in climate especially to photoperiod and temperature [6]. The optimum planting date primarily differs amongst cultivars of different maturity groups [7]. The effect of planting date on soybean grain yield depends on genetic and environmental conditions [8]. Therefore, the genotype × environment interaction study should be conducted to identify the varieties which are stable in different environments [9]. Day length is a key factor in most of the soybean varieties as they are short day plant and are sensitive to photo-periods. Baker [10] suggested that evaluation of soybean varieties under different planting dates is crucial in boosting production. In the present study we evaluated the growth pattern and yield of 10 soybean varieties in two different sowing dates under rainfed conditions in central India.

2. MATERIALS AND METHODS

A field experiment was conducted at Indian Institute of Soil Science, Bhopal during 2011-12 *kharif* seasons to evaluate the growth pattern and yield of 10 soybean varieties in two different sowing dates. The experiment was laid out in split plot design [11] with twenty treatment combinations comprising of two planting dates as main plots and ten varieties as subplots with 3 replications. The experimental soil is typical black soil (Vertisol) with pH 8.4, 0.5% organic carbon, 108.27 ppm available nitrogen, 1.36 ppm available phosphorus and 256.06 ppm available K. Seedbed was prepared by 2-3 times ploughing followed by leveling. Ten varieties of soybean (JS 335, JS 9560, JS 8021, JS 9752, NRC 12, JS 7105, NRC 37, NRC 7, JS 9305 and PS 1021) were sown with a gap of 15 days (July 2 and July 17) based on the onset of monsoon. The breeder seeds of these different varieties were obtained from Directorate of Soybean Research, Indore. The sowing was done manually at a seeding rate of 80 kg ha^{-1} at a row distance of 45 cm and in-between plant spacing of 5 cm.

2.1 Fertilizer Application and other Cultural Practices

A starter dose of N fertilizer @ 20 kg ha^{-1}, P fertilizer @ 60 kg ha^{-1}, K fertilizer @ 20 kg ha^{-1} and Zn fertilizer @ 5 kg ha^{-1} were applied at sowing as Urea (46-0-0), Single Super Phosphate (0-16-0), Muriate of Potash (0-0-60), Zinc Sulphate (21% Zn and 18% S). Plant population was maintained by thinning 15 days after germination to maintain plant to plant distance of 5 cm. Hoeing was done thrice to keep the crop weed free.

2.2 Data Recording and Analysis

Different varieties were harvested at different dates according to the maturity of the crop. At 50% flowering, the plant samples were collected by uprooting 5 plants randomly and oven-dried at 70°C and dry weight was recorded. Days to 50% flowering was recorded by counting the total number of days required for 50% of the total population to flower. Days to physiological maturity was recorded by counting number of days required to reach the entire plants to reach yellow and dry stage [12]. At harvest again 5 plants were harvested randomly from each plot

Table 1. Weather data during the experiment

Standard weeks	Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Bright sun shine hours
22	5.2	40.8	27.5	10.33
23	10.8	39.7	26.8	10.8
24	36.4	38.3	25.6	7.24
25	73.8	31.8	23.8	7.51
26	74.8	27.9	23.4	6.25
27	40.8	33.0	23.5	4.83
28	63.8	30.3	23.6	5.34
29	133.4	29.6	23.5	5.51
30	71.6	28.7	23.2	3.71
31	34.6	30.3	23.6	2.27
32	106.8	27.2	22.6	2.51
33	31.8	28.5	22.5	3.67
34	71.8	30.8	23.5	4.51
35	146.2	30.5	22.7	5.33
36	36.8	29.1	22.9	2.83
37	79.8	29.7	22.8	7.20
38	37.6	30.7	21.4	5.99
39	0	32.0	21.1	9.30
40	0	33.6	19.5	10.21
41	0	33.9	18.9	7.74
42	0	34.0	17.6	7.49
43	0	33.0	15.0	7.70
44	0	31.2	13.8	9.16
45	0	32.4	14.9	8.69
46	0	31.1	13.7	6.74

and observations on yield and yield components were recorded. Statistical analysis and interpretation of results were done by calculating values of C.D. (critical difference) at 5% level of probability through analysis of variance technique as described by Gomez and Gomez [13].

The weather data during the experiment is presented in Table 1 above.

3. RESULTS AND DISCUSSION

3.1 Dry Matter Production

Dry matter accumulation and their allocation in different plant parts are the key determinants for selecting high yielding genotypes [14]. In the present investigation it was found that delay sowing by 15 days resulted in a significant reduction in pre and post flowering dry matter production, pod and seed yield, and HI. It was evident from the data that the varieties significantly affected the pre flowering dry matter production in soybean (Table 3). Among the ten varieties, JS 8021(8.34 g plant^{-1}) accumulated significantly high dry matter at pre flowering, followed by JS 9752 (7.7 g plant^{-1}) compared to other varieties (Table 3).

Table 2. Days to 50% flowering in first sowing (D1) and second sowing (D2)

Varieties	D1	D2
JS 335	44	40
JS 9560	36	32
JS 8021	46	42
JS 9752	48	43
NRC -12	38	34
JS 7105	39	35
NRC 37	40	36
NRC-7	35	32
JS 9305	38	35
PS 1021	39	37

The varieties JS 8021 and JS 9752 are medium duration (100-115 days duration) varieties and they took more days to flower hence accumulated more pre flowering dry matter than the short duration varieties (JS 9560, JS 9305 and JS 7105). It has been reported that the pre flowering dry matter accumulation is a good accepted criterion for optimal yield [15]. But the prevailing weather conditions also played a significant role in the vegetative growth and further accumulation of dry matter in both pre and post flowering periods. The varieties also significantly affected the dry matter production at maturity in this study (Table 3). Soybean growth is determined by the amount of total dry matter accumulated in the plant and measured in units of g m^{-2} [16]. The highest dry matter production at maturity was recorded by the variety JS 9752 (12.73 g $plant^{-1}$) followed by JS 8021 (11.83 g $plant^{-1}$) (Table 3). The spreading nature of these varieties might be a reason for the more biomass accumulation in the pre- flowering period. Also, it was clear that only JS 9560 produced less biomass (29%) during the pre flowering period compared to other varieties and its major accumulation of dry matter was in the reproductive phase. Other varieties had dry matter accumulated in the ratio 35-40: 60-65 in the pre and post flowering period respectively.

The date of sowing also significantly affected pre flowering dry matter production (Table 3). The result showed that sowing at optimum date recorded significantly higher pre flowering DMP (7.65 g $plant^{-1}$), DMP at maturity (13.27 g $plant^{-1}$), and percent of post flowering DM partitioning into seed (46.45%). In the late sowing condition the variety JS 9752 accumulated more dry matter than the others. It was clear that delayed

Table 3. Effect of date of sowing on pre and post flowering dry matter production in soybean varieties

Treatments	**Dry matter production at 50% flowering (g $plant^{-1}$)**			**Dry matter production at maturity (g $plant^{-1}$)**		
Variety	**Date of sowing**			**Date of sowing**		
	D1	**D2**	**Mean**	**D1**	**D2**	**Mean**
JS 335	9.39 (38.2)	2.77 (33.3)	6.08	15.19 (61.8)	5.56 (66.7)	10.37
JS 9560	6.81 (29.6)	4.71 (43.2)	5.76	16.17 (70.4)	6.18 (56.8)	11.18
JS 8021	10.68 (41.6)	6.00 (41.0)	8.34	15.01 (58.4)	8.65 (59.0)	11.83
JS 9752	10.03 (38.0)	5.37 (37.2)	7.7	16.37 (62.0)	9.08 (62.8)	12.73
NRC -12	6.02 (38.1)	2.99 (33.6)	4.51	9.79 (61.9)	5.9 (66.36)	7.85
JS 7105	5.21 (34.7)	3.89 (39.1)	4.55	9.79 (65.3)	6.05 (60.9)	7.92
NRC 37	9.55 (36.0)	4.32 (40.8)	6.94	16.97 (64.0)	6.28 (59.2)	11.63
NRC-7	6.65 (39.9)	3.16 (34.5)	4.91	10.03 (60.1)	6.01 (65.3)	8.02
JS 9305	7.11 (33.9)	3.31 (37.3)	5.21	13.86 (66.1)	5.57 (62.7)	9.72
PS 1021	5.00 (34.5)	4.3 (39.8)	4.65	9.47 (65.5)	6.5 (60.22)	7.99
Mean	7.65	4.08		13.27	6.58	
Source	**SE (m)**	**CD (0.05)**		**SE (m)**	**CD (0.05)**	
Variety (V)	0.05	0.15		0.05	0.13	
Date of sowing (D)	0.11	0.33		0.1	0.29	
Interaction (V x D)	0.16	0.14		0.41		

(In parenthesis the per cent values are given)

sowing by 15 days was enough to decrease the biomass of soybean in the pre-flowering period. Late sowing affected the plant stature resulting in pre- mature flowering before the plant could attain its full size. The crop sown under late planting conditions could not accumulate sufficient dry matter because of lesser vegetative growth and reproductive period due to shorter day length. The proper mobilization of dry matter production towards the sink (seed yield) is an important factor for economic yield. Optimum environmental conditions should be provided to facilitate fullest expression of characters for the best classification of genotypes [17]. Some genotypes have more potential to translate assimilates towards economic yield due to differential response of genotypes [18]. In this study, delayed sowing advanced the time taken for 50% flowering by 4-6 days (Table 2). Further, the decreased rainfall and increased temperature in the later periods created moisture stress and also affected the overall growth and development of the crop under field conditions (Table 1). The length of the flowering and pod-filling phases of growth is known to be highly positively correlated with yield [19]. Soybean planted late in the season had less time to reach full vegetative growth and compensate this stage by completing its life cycle for seed yield. The interaction effect between varieties and sowing dates studied revealed that there was significant difference in the pre flowering dry matter production. The proportion of assimilates allotted to the reproductive plant parts during flowering and fruit set could be important in determining fruit set and seed number. Also the dry matter production between flowering and maturity was significantly highest for JS 9560 in first sowing followed by JS 9752 (Table 4). But the reverse was recorded by these varieties in the late sowing. This indicates that the variety JS 9560 could accumulate more dry matter if sown early in the season, but JS 9752 can accumulate relatively high post flowering dry matter even in the late sowing also. These are the characteristics of modern soybean varieties reported by Shiraiwa and Hashikawa [20] and Specht et al. [21]. This clearly put in the picture that the more sensitive the varieties to the adverse conditions the more yield loss would be there. In the case of per cent of post flowering dry matter production, the variety JS 9560 obtained higher value than the other varieties (Table 4). This trend is followed in both the sowing dates, but first sowing effectively contributed to the yield. Dry matter accumulation during the reproductive period strongly influences the yield and yield components [22,23]. The total dry matter level required for optimum seed number and yield per area is a useful growth criterion to predict optimal yield. Even though the varieties and sowing dates were significant in the dry matter accumulation in soybean, the date of sowing was more pronounced than the effect of varieties but the interaction effect of both decided the final yield.

3.2 Yield and Yield Attributes

Pod dry weight and seed yield significantly differ between sowing dates. The highest pod dry weight (5.02 g $plant^{-1}$) and seed weight (2.67 g $plant^{-1}$) were recorded in the first sowing. This was supported by the findings of Anderson and Vasilas [24]. They have concluded that delay in planting dates accelerate soybean flowering and leads to lower vegetative growth, which results in lower accumulation of dry matter and yield production.

The high seed yield might be due to the optimum temperature and moisture availability (Table 5). Carlson et al. [25] reported that a suitable planting date helps plants to take advantages of climatic factors such as temperature, moisture and day length.

Temperature, day length and variety can be important in determining the beginning of flowering and subsequent reproductive development in soybean. So any variation in the above factor from the optimum will reduce the yield. The yield of the soybean crop planted before or after the optimal planting period usually results in reduced yield [26,27,28]. Physiologically yield is dependent on availability of assimilates and it’s partitioning to economically important parts. Since the first sowing (optimum sowing) produced maximum dry matter in the vegetative as well as the reproductive periods resulted in the highest pod and seed weight. The sowing time has marked effects on growth and yield of most crops as delay in sowing beyond the optimum time usually results in yield reduction [29]. The pod and seed weight also differ significantly due to varieties. The highest pod weight (5.4 g $plant^{-1}$) and seed weight (3.19 g $plant^{-1}$) were recorded by JS 9560 followed by JS 9752 (4.1 g $plant^{-1}$ and 2.15 g $plant^{-1}$ respectively). All the varieties produced good amount of dry matter after flowering but this did not effectively contributed to yield in JS 8021, NRC 12 and JS 9305. But in other varieties, post flowering dry matter contributed more to yield.

Table 4. Effect of date of sowing in DMP and per cent contribution towards seed yield

Treatments	DMP between flowering and at maturity (g plant^{-1})			Percent of post flowering DM partitioning into seed		
Variety	Date of sowing			Date of sowing		
	D1	D2	Mean	D1	D2	Mean
JS 335	5.80	2.79	4.29	49.00	29.56	39.28
JS 9560	9.36	1.48	5.42	60.03	52.56	56.29
JS 8021	4.32	2.65	3.49	38.22	32.16	35.19
JS 9752	6.33	3.71	5.02	46.27	37.39	41.83
NRC -12	3.77	2.91	3.34	41.45	38.50	39.98
JS 7105	4.59	2.16	3.38	51.15	38.07	44.61
NRC 37	7.42	1.96	4.69	47.77	36.49	42.13
NRC-7	3.38	2.85	3.12	46.95	37.68	42.31
JS 9305	6.74	2.26	4.50	40.60	27.30	33.95
PS 1021	4.48	2.20	3.34	43.10	31.65	37.38
Mean	5.62	2.50		46.45	36.14	
Source	**SE (m)**	**CD (0.05)**		**SE (m)**	**CD (0.05)**	
Variety (V)	0.06	0.17		0.47	1.36	
Date of sowing (D)	0.13	0.38		1.06	3.03	
Interaction (V x D)	0.19	0.54		1.49	4.29	

Table 5. Pod and seed weight of soybean varieties

Treatments	Pod dry weight (g plant^{-1})			Seed yield (g plant^{-1})		
Variety	Date of sowing			Date of sowing		
	D1	D2	Mean	D1	D2	Mean
JS 335	5.71	1.86	3.78	2.83	0.83	1.83
JS 9560	9.03	1.76	5.40	5.61	0.77	3.19
JS 8021	2.70	1.92	2.31	1.65	0.85	1.25
JS 9752	5.12	3.08	4.10	2.91	1.39	2.15
NRC -12	3.54	2.15	2.84	1.56	1.12	1.34
JS 7105	4.65	2.22	3.44	2.33	0.83	1.58
NRC 37	5.9	1.84	3.87	3.54	0.71	2.13
NRC-7	3.29	2.05	2.67	1.59	1.07	1.33
JS 9305	6.57	1.38	3.98	2.74	0.62	1.68
PS 1021	3.70	1.74	2.72	1.92	0.70	1.31
Mean	5.02	2.00		2.67	0.89	
Source	**SE (m)**	**CD (0.05)**		**SE (m)**	**CD (0.05)**	
Variety (V)	0.03	0.08		0.02	0.05	
Date of sowing (D)	0.06	0.17		0.04	0.11	
Interaction (V x D)	0.09	0.25		0.05	0.15	

The variety JS 9560 showed highest pod yield followed by JS 9305 in the first sowing where as in the late sowing the highest pod yield was recorded by JS 9752 followed by JS 7105. However, the pod yield was drastically reduced in all the ten varieties in the late sowing. Shafigh et al. [30] reported that delayed soybean planting accelerates flowering, shortens vegetative and reproductive growth period and consequently, decreases grain yield. The variety JS 9305 recorded good pod yield in first sowing but failed to record enough pod yields in the second sowing. This indicates that this variety cannot survive and produce good yield under delayed sowing in rainfed regions. But, the variety JS 9752 is more promising even in the delayed sowing than the others with respect to yield and yield contributing factors. Even though the pod yield was high for other varieties the effective translocation was absent and hence there was no corresponding increase in seed yield. Planting season and cultivars and its interaction had significant effect on seed and biological yield [31].

The environmental factors like temperature, rainfall and sunshine hours played a great role in the translocation of photosynthetes to the economic part. Except JS 9752, all the varieties showed a drastic reduction in the seed yield in second sowing. The variety JS 9752 recorded 1.39 g seed per plant and this was nearly equal to the seed yield recorded by JS 8021 in first sowing. The variety JS 9305 recorded good seed yield in first sowing failed to give enough seed yields in the second sowing. This indicates that JS 9305 may not be a suitable variety for delayed sowing as it cannot withstand the changing conditions of soil moisture and temperature under rainfed conditions. Egli [19] showed the rate of seed dry matter accumulation to be influenced by planting date and genotype and that a planting date by genotype interaction exists. This clearly reveals that under rainfed conditions the selection of variety is most important criteria to get a good yield. High yielding varieties may not perform better under rainfed conditions because of moisture stress and high temperature. Also the time of sowing will determine the performance of the variety under field conditions. Salem [32] pointed out that sowing date plays an important role in soybean productivity and this is confirm by the present findings.

The genotypes showed significant difference in their harvest index in both sowing (Fig. 1). The harvest index also differed significantly with sowing dates also. The genotype JS 9560 recorded the highest HI followed by JS 7105 in the first sowing where as in the late sowing conditions the highest harvest index was recorded by NRC 12 followed by NRC 7. All the varieties except NRC 12 and NRC 7 recorded higher values of HI in the first sowing than the second sowing (Fig. 1). It was reported that the ultimate yield depends on the inherent harvest index of the plant [33]. Here the variety JS 9305 showed higher value of HI than JS 335 in first sowing. But in the late sowing this was reversed. All the varieties recorded a low HI in the second sowing. The difference in HI between first sowing and second sowing was more for JS 9560 and JS 7105.

Heydari zadeh and Khajepour [34] indicated that harvest index is affected by planting date. The study of Mirza Khani et al. [35] also supported these findings. In the present study we got similar results in the case of harvest Index. Seed yield and harvest index also associated with cultivar by planting date interactions [36,37].

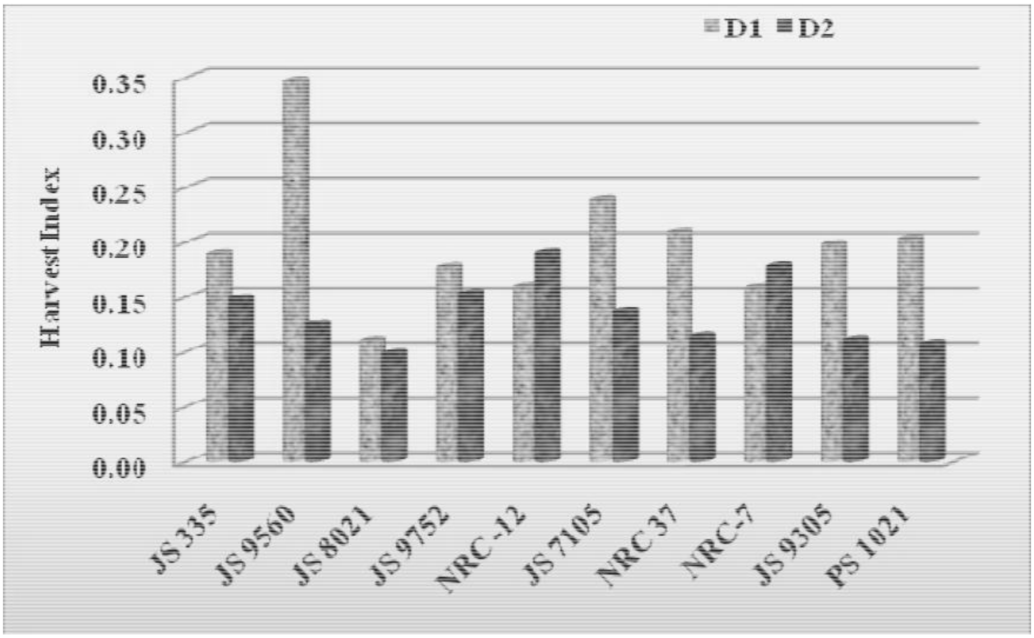

Fig. 1. Harvest Index (HI) of soybean varieties in two sowing dates

4. CONCLUSION

The present study suggested that early sowing with the onset of monsoon could be the optimum planting time for soybean to get better yield in Central India under rainfed conditions. From this study it was recommended that high yielding varieties like JS 9560 and JS 9305 are not suitable under adverse weather conditions in Central India. Hence if the sowing is delayed, one can select the suitable variety like JS 9752 which will give comparable yield in the later seasons. Therefore it is concluded that selection of suitable variety is the most important criterion where fluctuations in weather parameters are prevalent.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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