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Influence of Varieties and Planting Dates on Growth and Development of Soybean (*Glycine max* L. Merr) in Metekel Zone, North Western Ethiopia

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Abstract: Soybean (*Glycine max* L. Merr) is a new crop to Ethiopia introduced in about 1953 and has high potential in its nutritional value and yield in the country. Experiment was conducted in 2001/2002 to determine the influence of different planting dates on growth, dry biomass and grain yields of soybean varieties under Metekel Zone condition. A factorial combination of five varieties, TGX 133-2644, Clark 63K, Davis, Cocker 240 and Williams and four planting dates, May 24, June 8, June 23 and July 8 were employed in a split plot design with four replications at Pawe and Debatie. Varieties were allotted to, main plots and planting dates to subplot treatments. The analysis of variance of the data from the two locations revealed highly significant differences for varieties, planting dates as well as for varieties x planting dates interactions on most of growth and yield at both locations. Flowering was generally delayed and maturity hastened due to delay in planting dates. The magnitude of delay in flowering and hastening of maturity depended on varieties. Variety TGX133-2644 being the most late maturing variety as against the earliest variety Williams. Leaf area (LA) per plant and Leaf Area Index (LAI) were reduced significantly due to late planting and variety TGX133-2644 showed maximum LA and LAI. The extent of reduction in LA and LAI due to planting dates depended upon varieties. Yield of variety TGX133-2644 were significantly higher than those of other varieties at most of the sowing dates at both locations. Besides, this variety demonstrated maximum productivity (1998 and 1870 kg ha^{-1}) when planted on 8 and 23 June at both locations. In addition, the yield of variety Davis was quite stable (1307-1517 kg ha^{-1}) across all sowing dates at Pawe. Production of Davis was similarly high when planted on 24 May. It may, therefore, be concluded that TGX133-2644 may be planted on 8 or 23 June for maximum productivity at Pawe and variety Davis may be planted any time between 24 May and 8 July at this location. Cocker 240 and Clark 63 K may also be considered for planting on 8 June at Debatie. These results indicate that soybean cultivars and planting dates had impact on soybean growth, development and yield as well.

Key words: Soybean, variety, planting date

INTRODUCTION

Soybean is one of the important oil and protein crops of the world. Many developing countries in the tropics show interest in the production of soybean to meet their increasing demand for protein and vegetable oil. Remarkable improvements in the yields of this crop have been achieved through the development of high yielding cultivars. The yield potential of existing adapted cultivars can only be fully realized with proper management practices and timely performance of appropriate practices (Olufajo and Pal, 1991). Soybean is an important N_2-fixing leguminous crop, due to its high quality protein and input of combined N_2 into the soil (Smith, 1992). Soybean is known for its wide adaptability coupled with its higher productivity per unit area compared to other grain legumes (Boyer, 1982). Soybean, it is useful in crop rotation as its nodules fix atmospheric nitrogen and thus builds up the soil fertility by fixing large amount of atmospheric nitrogen through the root nodules and also through leaf fall on the ground at maturity (Singh, 1983). Studies have shown the optimum rate of N applied for cereal crop production is less following soybean than following non-leguminous crops (Varvel and Peterson, 1992).

Soybean has a great potential for Ethiopia, as it has been duly recognized by many researchers and research organizations for its economic importance (IAR, 1982) and its domestic demand, for various uses, is growing. Soybean is one of the most important feed stuffs for livestock either in form of forage (as hay and silage) or soybean meal, which contains much high quality protein

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(IITA, 1990). Hence, production of soybean in Ethiopia is very essential to overcome malnutrition and partially compensate the expensive sources of animal proteins. Thus, the processing of protein rich soymilk, soy cheese, defatted soy flour and other products have been successfully produced and utilized to a certain extent. Production of this crop is indispensable in the country to enrich the staple cereal based food with sufficient and high quality protein.

In Ethiopia, soybean can also used as cover crop in coffee plantations to enrich the soils with nitrogen. Moreover, this crop can supplement nitrogen in cropping systems in subsistence farming and large scale farming involving cereals such as maize, sorghum, millet and others. In Ethiopia, investigations have been going on, on various aspects of soybean for the past several decades with encouraging results (JATS, 1956; IAR, 1982). Concerted efforts are required to increase the soybean productivity in the country specifically to combat the protein malnutrition of the growing population. For increasing production of any crop, specifically like soybean with photo-thermo-insensitive varieties, in a country like Ethiopia with erratic rainfall and complex environmental conditions, identification of appropriate varieties, as one of the low cost inputs in production technology with non-monetary input such as date of planting is most important (Pal *et al.*, 1983; Pal and Olufajo, 1988; Olufajo and Pal, 1991).

Seed quality is determined by its viability and vigor, which depends upon the conditions under which the seed has been produced. Appropriate date of sowing is not only important for proper germination and emergence but also to have the crop in the field when environmental conditions are conducive for maximum growth and development as environment has a pronounced effect on the growth and development of plants. Length of photoperiod strongly influences the morphology of soybean plant by causing changes in the time of flowering, maturity and dry matter production. Soybean cultivars do not have the same critical day length. Therefore the effect of planting date on the number of days to flowering, maturity, dry matter production and grain yield will be different for different cultivars. Therefore, to increase the soybean productivity in Metekel zone of north western Ethiopia, the study was conducted with the objective to determine the influence of different planting dates on growth, dry biomass and grain yields of soybean varieties under Metekel Zone condition, north western Ethiopia.

MATERIALS AND METHODS

The experiment was conducted during 2001 cropping season at Pawe Agricultural Research Center of the Ethiopian Agricultural Research Organization (EARO) and at Debatie on farmer's field. Both sites are located in the north western part of Ethiopia. The soybean varieties used for this study were TGX133-2644 (V1), Clark 63K (V2), Davis (V3), Cocker 240 (V4) and Williams (V5). The experimental design was split plot with four replications with varieties as the main plots and dates of planting as sub plot treatments. There were four planting dates at an interval of 15 days, 24 May, 8 June, 23 June and 8 July, 2001 designated as P1, P2, P3 and P4, respectively. Factorial combination of the 5 varieties TGX133-2644 (V1), Clark 63K (V2), Davis (V3), Cocker 240 (V4) and William (V5) and 4 planting dates i.e., 24 May, 8 June, 23 June and 8 July were laid out in a split plot design at Pawe and Debatie. Each sub plot consisted of six rows of 5 m length spaced at 40 cm apart (2.40×5.00 m). Intra-row spacing was 10 cm. Four central rows leaving 0.5 m at both ends of rows were used as net plot (1.60×4.00 m) and were considered for data collection. One hundred kg ha^{-1} of DAP was applied to all plots at the time of planting. Other cultural practices were followed as recommended for soybean crop production (IAR, 1982).

Data collection and procedures

Phenological observations: Days to 50% crop emergence, 50% flowering and 50% maturity were recorded when 50% of the plants in a plot reached their respective phenological stages.

Growth: Plant height was recorded on five randomly sampled plants in the four middle rows (net plot area) by measuring the main stem height in centimeter from the ground upto the apex of stem tip of each plant at maturity. Leaf area was determined using Punch Technique (Pal and Saxena, 1977) on five randomly sampled plants at 50% flowering stage. All leaves (excluding petiole) of 5 plants were sampled and their fresh weights were recorded. They were mixed thoroughly and 25 leaves were randomly sampled and stacked in a tray. The leaf discs from two punches/leaf were taken out from all 25 leaves. Hence, 50 leaf discs were punched out and their fresh weights (all 50 discs) recorded. Leaf area (LA) was calculated as follows:

$$LA/5 \text{ plants} = \pi r^2 nW/ W$$

where, r = radius of punch, n = number of leaf discs (50), w = fresh weight of all leaf discs (50), W = total fresh weight of all leaves $plants^{-1}$ and π = 3.14. Leaf area index was calculated as the ratio of leaf area /plant to the area occupied by a plant.

Yield: Yield was recorded from central four rows leaving 0.5 m at both ends of the rows (1.6×4.0 m). Grain yield and dry biomass yield $plant^{-1}$ were determined on five randomly sampled plants (as for number of branches per plant). Grain yield $plant^{-1}$ was taken at 12.5% moisture content and dry biomass yield $plant^{-1}$ was determined after sun drying for three weeks. Grain yield/plot was recorded from each net plot area separately and expressed as kg ha^{-1} at 12.5% moisture content. Dry biomass yield/plot was recorded after sun drying for three weeks and converted into kg ha^{-1}.

Data analysis: Data were subjected to the analysis of variance appropriate to the design of the experiment (Gomez and Gomez, 1984) using an MSTAT-C statistical software (Michigan State University, 1989). Least Significant Differences (LSDs) at 5% level of probability were computed to delineate significant difference between and /or among treatment means.

RESULTS AND DISCUSSION

Days to 50% crop emergence: Analysis of variance revealed that main effect of varieties was significant in influencing the crop emergence at Debatie only whereas main effect of planting dates was significant in influencing the crop emergence at both locations, i.e., Pawe and Debatie (Table 1). At Debatie, Clark 63K took significantly more number of days to emerge than all other varieties, which took almost similar number of days to emerge. This result agreed with the report by IAR (1982) showing variety variations in days to 50% crop emergence. Crop emergence is normally affected due to moisture content of soils, soil types, crust formation on top soil, temperature and seed factors specially the thickness and/ or hardiness of seed coat. Among all varieties, Clark 63K has relatively hard seed coat that might have impeded the permeability of water into seeds and thus delayed its emergence by a fraction of day. However, this phenomena was not observed at Pawe. At Pawe with respect to planting date, crop emergence was significantly delayed when planting date was delayed from last week of May (24 May) to third week of June (23 June). However, planting in the first week of July (8 July), significantly hastened crop emergence compared to earlier planting date (Table 1). Similarly, at Debatie also last date of planting hastened the crop emergence significantly compared to all earlier dates of planting. At both locations, light showers frequently occurred in second week of July and hence this may have facilitated the emergence of soybean faster.

Days to 50% flowering: Days to 50% flowering of soybean were significantly affected by both the main effects of soybean varieties and planting dates as well as by their interactions at both locations (Table 2). Averaged over planting dates, at both locations, Variety TGX 133-2644 took the longest number of days to flower (43 and 48 days at Pawe and Debatie, respectively) as against an early variety Williams, which took 33 and 35 days to flower at Pawe and Debatie, respectively. Other varieties Davis, Cocker 240 and Clark 63K were intermediate in days to flowering and differed significantly in descending order at both locations. The significant variations in flowering days are seem

Table 1: Main effect of soybean varieties and planting dates on days to 50% crop emergence at Pawe and Debatie

Variety	Pawe	Debatie	Planting date	Pawe	Debatie
TGX133-2644	7.0	7.3	24 May	7.2	7.7
Clark 63K	6.9	7.6	8 June	7.0	7.8
Davis	7.1	7.2	23 June	8.0	7.6
Cocker 240	7.1	7.1	8 July	6.1	6.2
Cocker 240	7.1	7.1			
Williams	7.0	7.2			
$LSD_{0.05}$	NS	0.25	$LSD_{0.05}$	0.43	0.28
CV%	9.5	6.1	CV%	9.5	6.1

NS: Non significant

Table 2: Effect of planting dates on days to 50% flowering of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	33	42	47	49	43	34	47	52	60	48
Clark 63K	29	36	39	42	37	34	32	46	48	40
Davis	30	38	44	44	39	35	43	49	49	44
Cocker 240	26	34	38	41	35	30	38	42	46	39
Williams	22	33	36	40	33	26	35	39	41	35
Mean	28	37	41	43		32	39	46	49	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	0.60	0.38	1.30	0.47	0.38	0.84
CV%		2.60			1.43	

to varietal characteristics. Averaged over soybean varieties, the earliest planting date caused early flowering (28 and 32 days) at Pawe and Debatie, respectively. Flowering was significantly delayed with delay in each planting date and consequently last planting date (8 July) caused soybean plants to flower at 43 and 49 days, respectively at Pawe and Debatie (Table 2). Interactions between varieties and planting dates were significant on 50% flowering at both locations and each variety exhibited delay in flowering due to delayed planting (Table 2). However, the magnitude of delay in flowering due to delayed planting in variety William was much greater than that in Clark 63K, Davis, Cocker 240 and TGX133-2644 at Pawe. However, at Debatie the magnitude of delay in flowering due to delayed planting was much greater in TGX133-2644 than that in other varieties (Table 2). In any case, variety TGX 133-2644 took the longest time to flower irrespective of planting dates at both locations (Table 2).

Days to 50% maturity: Similar to days to 50% flowering, maturity duration was also significantly affected by the main effects of varieties and planting dates as well as by their interaction at both locations (Table 3). Averaged over planting dates, TGX 133-2644 took longest duration of (104 at Pawe and 113 days at Debatie) to mature and variety Williams was the earliest to mature. Clark 63K, Davis and Cocker 240 were intermediate in 50% maturity duration and significantly differed in their maturity duration in descending order at both locations. Averaged over varieties, delayed planting date hastened the maturity significantly and consequently soybean planted at first planting date (24 May) took longest duration of 104 and 109 days to mature at Pawe and Debatie, respectively. Whereas soybeans planted at last planting date, (8 July) took short duration of 82 days at Pawe and 91 days to mature at Debatie, respectively. Interaction between soybean varieties x planting dates revealed that delay in planting hastened the maturity of all the varieties at both locations significantly. However, the magnitude in the reduction of maturity duration due to delay in planting dates differed significantly at Pawe. Variety Cocker 240 planted on 8 July matured 18 days earlier than that planted on 24 May whereas other varieties planted on 8 July matured 14-15 days earlier than those planted on 24 May. On the contrary, at Debatie, variety Davis planted on 8 July matured 22 days earlier than that planted on 24 May, whereas other varieties planted on 8 July matured 13-16 days earlier than was the case when planted at first planted date (24 May). Nevertheless, variety TGX 133-2644 matured at the last compared to all other varieties irrespective of planting dates. This result agrees with Carter and Boerma (1979) who reported that significant responses from the genotype x planting date interaction affecting maturity date, flowering date, lodging and plant height at flowering. In general, delayed time of sowing shortened the maturity of soybean varieties in the present investigation and such results have earlier been reported by several workers (Cartter and Hartwing, 1962; Pal *et al*., 1983; Olufajo and Pal, 1991).

Plant height: Both main effects as well as interactions between varieties and planting dates significantly affected plant height at maturity at Pawe and Debatie (Table 4). At both locations, variety TGX 133-2644 produced the tallest plants compared to all other varieties. Plants of Davis were short at Pawe and other varieties produced plants of intermediate height at this location. At Debatie, however, plant height of varieties Davis, Cocker 240 and Williams were statically similar and that of Clark 63K was intermediate (Table 4). Averaged over varieties, delay in planting dates resulted in significantly reduced plant height and 8 July planting produced significantly shorter plants than was the case with earlier plantings at both locations (Table 4). However, at Pawe, planting on 24 May produced significantly shorter plants than other two mid planting dates (Table 4).

Table 3: Effect of planting dates on days to 50% maturity of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	118	109	94	93	104	121	115	109	105	113
Clark 63K	108	98	87	79	93	111	104	96	86	99
Davis	110	101	91	85	97	114	107	100	92	103
Cocker 240	97	92	85	79	88	103	97	93	89	96
Williams	88	84	76	74	81	95	90	87	82	89
Mean	104	97	87	82		109	103	97	91	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	0.80	0.58	1.29	0.43	0.51	1.15
CV%		0.90			0.80	

The interaction effect of variety x planting date at Pawe indicated that, varieties TGX 133-2644 and Clark 63K produced significantly taller plants when planting date was delayed from 24 May to 8 June. However, late planting of TGX 133-2644 exhibited significant reduction in plant height but plant heights of Clark 63K was not affected. Davis had identical plant heights in first three dates of planting and produced significantly shorter plants when planted on 8 July. Furthermore, plant height of Cocker 240 and Williams were statistically similar to 24 May and 8 June plantings but plant height was reduced significantly due to late planting. At Debatie, variety TGX 133-2644 produced statistically similar plant heights at first and second planting dates and at third (June 23) planting date plant heights were significantly increased. However, plant height was significantly reduced when planted on 8 July. Variety Clark 63K and Davis produced statistically similar plant heights at first, second and third planting dates followed by a significant reduction in plant height due to 8 July planting. However, plant heights of Cocker 240 and Williams were statistically similar at first and second planting dates and were significantly reduced due to delayed planting (8 July). In general, the results of the present investigation clearly brings out the fact that delayed planting resulted in reduced plant heights, though the degree and trend in plant height varied with varieties. Such results are not unusual and have been reported by several workers in temperate (George, 1961; Cartter and Hartwig, 1962, Carter and Boerma, 1979) and tropical (Pal *et al*., 1983; Olufajo and Pal, 1991) climates.

Leaf area plant^{-1}: Analysis of data on leaf area (cm^2 plant^{-1}) at 50% flowering exhibited that the main effects of variety and planting dates significantly affected at both locations. The interaction between varieties x planting dates had significantly affected leaf area at Debatie only (Table 5). At both locations, averaged over planting dates, variety TGX 133-2644 produced the largest leaf area compared to all other varieties. At Pawe, variety Cocker 240 produced the smallest leaf area and leaf areas produced by the other three varieties were intermediate. However, at Debatie, Clark 63K, Cocker 240 and Williams had statistically identical leaf areas, which were significantly smaller than that produced by variety Davis. Averaged over soybean varieties, the earliest date of planting resulted in largest leaf area at both locations. Leaf area was significantly reduced as planting dates were delayed approaching to the minimum at the last date of planting (Table 5). At Debatie, the interaction between

Table 4: Effect of planting dates on plant height (cm) of soybean varieties at maturity at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	43.1	47.2	42.4	40.2	43.2	50.3	50.1	56.2	48.0	51.1
Clark 63K	18.1	31.0	30.0	29.1	27.0	38.1	37.0	36.1	33.1	36.0
Davis	25.0	27.0	27.2	19.1	24.5	34.1	32.2	31.0	27.0	31.0
Cocker 240	32.1	31.0	19.0	19.1	25.3	36.2	33.1	32.0	27.1	32.1
Williams	37.2	36.3	32.4	29.4	34.4	35.3	33.0	31.1	16.0	29.0
Mean	31.1	34.5	30.2	27.3		38.8	37.0	37.2	30.2	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	1.45	1.23	2.74	3.66	1.55	3.46
CV%		6.26			6.79	

Table 5: Effect of planting dates on leaf area (cm^2)/plant at 50 % flowering stage of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	2453	2153	2078	1530	2054	2479	1889	1385	687	1573
Clark 63K	1174	1051	1232	952	1102	1581	909	811	692	998
Davis	1735	1180	970	737	1155	1836	1628	945	845	1314
Cocker 240	1304	955	958	738	989	1048	990	919	859	954
Williams	1903	1308	930	878	1255	949	839	819	813	855
Mean	1714	1329	1233	967		1578	1251	975	779	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	200.5	207.5	NS	184.4	99.5	223
CV%		24.86			13.67	

NS-non significant

planting dates and varieties revealed that TGX 133-2644, Clark 63K and Davis produced the largest leaf area at first planting date (24 May) and the lowest leaf area at the last planting date (8 July). Variety TGX 133-2644 showed significant decline in leaf area with delay in each planting date. Variety Clark 63K also had significantly smaller leaf area when planted later as compared to that at 24 May planting. However, variety Davis had statistically identical leaf area index when planted on 24 May and 8 June and leaf area declined significantly due to later planting dates. On the contrary to the above three varieties, leaf area of Cocker 240 and Williams was not influenced by planting dates. In the present investigation, Leaf area and leaf area indices of variety TGX 133-2644 due to early plantings at Pawe and Debatie were slightly larger than the leaf area index (ranging from 3.0-4.6) reported by other researchers (Pal and Saxena, 1977; Shibles and Weber, 1965; Shibles and Sundberg, 1998; Morrison *et al*., 1999; Kumudini *et al*., 2001). It should be noted, however, that soybean plant population maintained in the tropics and sub tropics are usually higher (more than 500,000 plants ha^{-1}) (Pal and Saxena, 1977; Olufajo and Pal, 1991) as compared to 250,000 plants ha^{-1} in the present investigation and thus slightly larger leaf area per plant was produced due to wider spacing, especially in the case of TGX133-2644 planted in May or early June.

Grain yield plant^{-1}: Analysis of variance revealed that grain yield plant^{-1} was significantly affected by main effects of soybean varieties and planting dates as well as by their interaction at Pawe and Debatie (Table 6). At Pawe TGX 133-2644 produced the highest yield plant^{-1} and Williams produced the least yield plant^{-1}. Clark 63K, Davis and Cocker 240 produced intermediate levels of yield plant^{-1}. At Debatie, however, averaged over planting dates TGX133-2644 and Cocker 240 yielded significantly higher than Clark 63K and Williams. Grain yield plant^{-1} of Davis was intermediate. Averaged over varieties at both locations, highest yield plant^{-1} was observed in case of 24 May planting and yield levels significantly decreased at later planting dates, yield per plant being minimum due to 8 July planting. Significant interaction between soybean varieties x planting dates on grain yield per plant at Pawe and Debatie indicated that varieties responded differently when planted at different dates (Table 6). At Pawe, TGX 133-2644 planted on 24 May outyielded all other varieties at all planting dates. Furthermore, the yield plant^{-1} of TGX 133-2644 was stable until 23 June planting and declined significantly due to 8 July planting. Clark 63K and Davis exhibited significant reduction in grain yield plant^{-1} when planting date was delayed throughout from 24 May until 8 July planting. In case of Cocker 240, there were identical yields plant^{-1} when planted on 24 May and 8 June but its yield plant^{-1} significantly declined due to later planting dates. In Williams, yield plant^{-1} increased significantly when planting was delayed from 24 May to 8 June and thereafter yield plant^{-1} were identical until last planting date (8 July). At Debatie, variety TGX 133-2644 yielded lowest on 24 May planting and grain yield plant^{-1} significantly increased when this variety was planted on 8 June and 23 June followed by significant decline in yield plant^{-1} due to 8 July planting. On the other hand, Clark 63K, Davis, Cocker 240 and Williams exhibited significant decline with delay in planting dates giving lowest yield on 8 July planting.

Dry biomass yield plant^{-1}: Unlike the grain yield plant^{-1}, dry biomass yield plant^{-1} was significantly affected by main effects of soybean varieties and planting dates at both locations but their interactions were not significant (Table 7). TGX 133-2644 and Davis produced statistically identical dry biomass yield plant^{-1} at Pawe, which were significantly greater than that produced by Williams. Clark 63K and Cocker 240 produced intermediate levels of dry biomass yield plant^{-1}. At Pawe, however, TGX 133-2644 produced the highest dry biomass yield plant^{-1} followed by Davis. Variety Clark 63K and Williams produced the lowest biomass yield plant^{-1}. Averaged over soybean varieties, dry biomass yield plant^{-1} significantly

Table 6: Effect of Planting dates on grain yield (g)/plant of soybean varieties at Pawe and Debatie

	Date of planting date (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	11.27	8.12	11.72	4.72	8.95	2.54	4.63	5.41	3.05	3.90
Clark 63K	5.6	4.52	3.50	1.82	3.86	3.84	2.40	2.06	1.35	2.41
Davis	5.82	4.60	3.20	2.9	4.13	4.53	3.02	3.45	2.74	3.43
Cocker 240	4.72	5.15	2.57	1.6	3.51	4.55	4.11	4.10	3.50	4.06
Williams	1.95	2.92	3.70	2.85	2.85	3.83	2.52	2.51	1.49	2.58
Mean	5.87	5.06	4.95	2.77		3.85	3.33	3.50	2.42	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	0.67	0.38	0.84	0.81	0.44	0.98
CV%		12.65			21.13	

decreased with delay in planting date from 24 May to 8 July at Debatie, whereas at Pawe soybean planted on 23 June produced significantly greater dry biomass yield per plant than all other planting dates (Table 7).

Harvest index: Harvest index was calculated as the ratio of grain yield plant^{-1} to dry biomass yield plant^{-1}. It was significantly affected by main effects of varieties and interaction between variety and planting date at Debatie, whereas both main effects of varieties and planting date as well as their interaction affected the harvest index significantly at Pawe (Table 8). At Debatie, the main effects of varieties indicated that Cocker 240 had the largest harvest index followed by TGX 133-2644, William and Davis, which had statistically identical harvest index. Clark 63 K had the lowest harvest index. At Pawe, however, variety TGX 133-2644, Clark 63K and William had significantly higher harvest index than Davis. Cocker 240 had intermediate harvest index at Pawe in contrast to the maximum harvest index exhibited by this variety at Debatie. Averaged over all varieties harvest indices were statistically similar at different planting dates at Debatie. At Pawe, however, maximum harvest index was recorded due to 24 May planting which was significantly reduced when planting date was delayed from 23 June onwards. At Pawe, variety TGX133-2644 had higher harvest index due to 24 May planting (in contrast to that of Debatie) and harvest index of this variety increased significantly due to later dates of planting. In variety Clark 63K, harvest indices due to 24 May and 23 June, planting were significantly greater than those recorded from 8 June and 8 July planting dates. Other varieties did not show much difference in their harvest index due to planting date except variety Williams which had significantly higher harvest index due to 8 June planting than due to other planting dates (Table 8). At Debatie, interaction between variety and planting date revealed that harvest index of variety TGX133-2644 was lowest due to 24 May planting and was increased significantly with later planting dates reaching to the maximum due to 8 July planting (Table 8). On the contrary, in Clark 63K, harvest index was significantly greater due to 24 May planting than those due to later planting dates; whereas in Davis mid-planting dates caused significantly low harvest index than other planting dates.

Table 7: Main effect of varieties and planting dates on dry biomass yield (g) /plant at Pawe and Debatie

Variety (V)	Pawe	Debatie	Planting date	Pawe	Debatie
TGX 133-2644	16.7	8.7	24 May	9.2	9.2
Clark 63K	6.2	7.0	8 June	9.1	7.9
Davis	10.9	8.3	23 June	11.5	6.7
Cocker 240	8.1	7.5	8 July	8.7	5.7
Williams	6.1	5.4			
$LSD_{0.05}$	1.43	0.86	$LSD_{0.05}$	1.41	0.49
CV%	23.10	10.37	CV%	23.10	10.37

Dry biomass yield ha^{-1}: The data on dry biomass yield ha^{-1} revealed that main effects of varieties and planting dates and their interactions were significant in influencing the biomass yield ha^{-1} at both locations (Table 9). Averaged over planting dates, TGX 133-2644 produced the highest dry biomass ha^{-1} of all varieties and Williams produced the lowest dry biomass ha^{-1} at both locations. Other varieties had intermediate levels of dry biomass yield ha^{-1}. With respect to main effects of planting date at Pawe, delay in planting date from 24 May to 8 June increased the dry biomass yield ha^{-1}. Furthermore, dry biomass yield ha^{-1} obtained from 8 June, 23 June and 8 July plantings were comparable. At Debatie, dry biomass yield ha^{-1} significantly increased when planting date was delayed from 24 May to 8 June. Further delay in planting dates resulted in significant decline in the dry biomass yield ha^{-1} at this location. Interaction effect between soybean varieties and planting dates at Pawe exhibited similar biomass yield of TGX 133-2644 variety from first three planting dates (May 24, 8 June, 23 June) and thereafter its dry biomass yield significantly declined (Table 9). At this location Clark 63K, Davis and Cocker 240 produced the highest biomass yield ha^{-1} on

Table 8: Effect of planting dates on harvest index of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	0.85	0.46	0.59	0.38	0.46	0.29	0.41	0.41	0.58	0.43
Clark 63K	0.68	0.47	0.61	0.37	0.53	0.49	0.33	0.30	0.35	0.36
Davis	0.41	0.39	0.40	0.31	0.37	0.45	0.33	0.35	0.53	0.41
Cocker 240	0.45	0.50	0.38	0.32	0.41	0.47	0.56	0.56	0.48	0.51
Williams	0.42	0.67	0.44	0.41	0.48	0.41	0.42	0.47	0.40	0.42
Mean	0.56	0.49	0.48	0.37		0.42	0.41	0.42	0.46	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	0.08	0.06	0.13	0.06	NS	0.11
CV%		20.67			17.9	

NS: Non significant

8 June plantings and dry biomass yield ha^{-1} of these varieties were significantly lower on 8 July planting compared to that from 8 June planting. Williams however, produced the highest dry biomass yield ha^{-1} when planted on 24 May and its biomass yield tended to decline when planted at later dates and 8 July planting produced lower biomass yield ha^{-1} as compared to 24 May and 8 June plantings. At Debatie, interaction between planting dates and variety revealed that variety TGX 133-2644, Davis and Cocker 240 produced significantly greater dry biomass yield when planted on 8 June than on 24 May (Table 9). Further delay in planting dates of these varieties significantly reduced their dry biomass yield ha^{-1}. Variety Clark 63K, on the other hand, produced significantly greater biomass yield ha^{-1} when planted on 24 May and its biomass yield ha^{-1} significantly declined due to later planting dates. Williams, however, yielded similar dry biomass yield ha^{-1} when planted on 24 May and 8 June and its dry biomass yield ha^{-1} was significantly increased on 23 June planting. Furthermore, delay in planting dates on 8 July caused this variety to show a significant and drastic reduction in dry biomass yield ha^{-1}.

Grain yield ha^{-1}: Data on grain yield ha^{-1} indicated that both main effects of varieties and planting dates and their interaction affected grain yield ha^{-1} significantly at both locations (Table 10). Averaged over planting dates, variety TGX 133-2644 and Davis outyielded all other varieties at Pawe. However, variety TGX 133-2644 outyielded all other varieties at Debatie (Table 10). Averaged over varieties, soybean planted on 8 June and 23 June produced significantly higher grain yield ha^{-1} than that on 24 May and 8 July at Pawe. However, yield obtained due from 24 May planting was also significantly greater than grain yield ha^{-1} obtained from 8 July planting at Pawe. At Debatie, soybean planted on 8 June produced significantly greater yield than those obtained due to other planting dates. Furthermore, soybean yields obtained from plantings on 24 May and 23 June were statistically similar and significantly greater than that obtained from 8 July planting. Interaction effects between varieties and planting dates indicated that variety TGX 133-2644 exhibited significant increase in grain yield ha^{-1} when planting date was delayed from 24 May to 8 June at Pawe (Table 10). Thereafter, yield of this variety were statistically identical when planted on 8 June and 23 June. However, grain yield ha^{-1} of this variety was significantly reduced when planted on 8 July. Furthermore, yields of all other varieties at Pawe were similar at all planting dates except in the case of Clark 63K which produced significantly greater grain yield ha^{-1} when planted on 8 June as compared to that planted on 8 July. Interaction

Table 9: Effect of planting dates on dry biomass yield (kg ha^{-1}) of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	3190	3609	3533	2772	3276	2295	3284	2582	2342	2625
Clark 63K	1569	1899	1322	1235	1506	2301	1650	1576	1311	1709
Davis	1471	2890	2432	2245	2259	1355	2206	1706	823	1522
Cocker 240	1461	2272	1456	1281	1617	1179	2615	1732	1205	1682
Williams	1783	1392	1318	745	1309	1450	1459	1809	439	1289
Mean	1687	2183	1931	2173		1513	2226	1742	1581	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	298	260	587	112	81	182
CV%		20			15.5	

Table 10: Effect of planting dates on grain yield (kg ha^{-1}) of soybean varieties at Pawe and Debatie

	Date of planting (P)									
	Pawe					Debatie				
Variety (V)	24 May	8 June	23 June	8 July	Mean	24 May	8 June	23 June	8 July	Mean
TGX 133-2644	1359	1998	1870	427	1414	439	1526	1249	1220	1108
Clark 63K	659	704	684	423	618	907	1140	771	634	864
Davis	1307	1372	1519	1333	1382	793	630	701	476	650
Cocker 240	633	891	717	669	728	935	1376	455	440	802
Williams	745	647	667	495	638	625	802	1102	188	679
Mean	940	1122	1091	669		739	1094	855	591	

	Pawe			Debatie		
Analysis	V	P	VXP	V	P	VXP
$LSD_{0.05}$	150	124	278	170	104	233
CV%		20.41			9.28	

between variety and planting dates at Debatie indicated that variety TGX 133-2644 and Cocker 240 showed significant increase in yield ha^{-1} when planting date was delayed from 24 May to 8 June (Table 10). Thereafter, soybean yield of these varieties significantly declined due to planting on 23 June and 8 July. Variety Clark 63K produced statistically similar grain yield ha^{-1} when planted on May 24 and 8 June. Grain yield ha^{-1} of this variety was significantly lower when planted on 23 June and 8 July than that on 8 June. On the contrary, Davis did not show any response of planting dates on grain yield at this location similar to that of Pawe except that yield of 8 July planted crop was significantly lower than that of 24 May planted crop. However, Williams produced statistically identical yields due to planting at 24 May and 8 June and its yield significantly increased due to 23 June planting. Thereafter, yield of this variety was significantly reduced due to 8 July planting. Furthermore, variety TGX 133-2644 (except the ones planted on 8 July at Pawe and 24 May at Debatie) outyielded all other varieties at all planting dates.

It is worth mentioning that TGX 133-2644 outyielded all other varieties at most of the planting dates primarily because this variety had greater number of pods per plant compared to other varieties at most of the planting dates at both location (Table 6). Variety Davis closely followed TGX133-2644 in most of the growth and yield attributes and yielded significantly higher yield ha^{-1} than the other varieties.

Several researchers have attempted to identify critical periods of soybean yield determination (Egli, 1998; Board and Harville, 1993; Hayati *et al*., 1995; Board *et al*., 1996). Neither the duration of vegetative period with dry matter accumulation during vegetative period nor duration of this period with grain yield have been reported to have consistent and positive relationship (Egli, 1993). However, many researchers have reported quite reasonable degree of relationship between pod-filling period and seed yield of soybean (Hanway and Weber, 1971; Gay *et al*., 1980; Smith and Nelson, 1986) but quite a few reports are available contesting this relationship as well (Egli *et al*., 1984; Egli and Crafts-Brandner, 1996). Hence, the reduced period between days to 50% flowering and maturity due to delayed plantings (Table 2 and 3) observed in this investigation might not have affected productivity of soybean varieties specially that of TGX133-2644, Davis and Cocker240 (Table 10) in case of June plantings. In general, the effect of planting date on yield was variety and site specific. Based on the results, variety TGX133-2644 may be planted in June at Pawe and Debatie; whereas variety Davis may be planted any time starting from fourth week of May to first week of July at Pawe.

CONCLUSIONS

Variety TGX133-2644 was late maturing variety, which took longest day to flower and mature as against Williams, which took minimum number of days to flower and to mature at both locations. Delay in planting dates produced shorter plants. The reduction in plant height due to planting dates varied with varieties. Leaf area and leaf area index were significantly affected by variety, planting date and their interactions. Variety TGX133-2644 produced the largest leaf area and LAI and Cocker 240 produced the smallest leaf area and LAI. Delay in planting dates reduced leaf area and LAI significantly and the magnitude in the reduction of leaf area and LAI varied with the varieties. Furthermore, TGX133-2644 produced the highest leaf area and LAI when planted at most of the planting dates as compared to other varieties at most of the planting dates. Grain yield per plant were much higher at Pawe than Debatie. Variety TGX133-2644 produced the highest grain yield per plant at Pawe whereas variety TGX133-2644 and Cocker 240 produced significantly greater grain yield per plant than other varieties at Debatie. May and June plantings caused significantly greater yields than July plantings. Most of the varieties produced significantly greater yields when planted either 8 June or 23 June compared to 8 July planting. Harvest index was significantly affected by variety and planting date interaction at both locations. Variety TGX133-2644 produced significantly greater harvest index at 8 July planting compared to other varieties at most planting dates at Debatie while it produced significantly greater harvest index due to 24 May plantings than others at Pawe. Other varieties showed not much variation in harvest index due to planting dates. Dry biomass yield ha^{-1} produced by TGX133-2644 was much higher than all other varieties at most planting dates at both locations. Variety Davis, however, was next high producer of biomass yield at Pawe particularly when planted in June or early July at Pawe. Averaged over all varieties, 8 June planting results significantly higher biomass yield than those due to other planting dates at both locations.

Grain yield ha^{-1} was significantly affected by variety, planting dates as well as by their interaction at both locations. Variety TGX133-2644 and Davis outyielded all the varieties at Pawe, whereas, the former also outyielded all the varieties at Debatie. Soybean planted on 8 June and 23 June produced significantly higher grain yield ha^{-1} than those planted on 8 July at both locations. Variety TGX133-2644 produced significantly greater yield when planted during June whereas, Davis had fairly stable yield levels across the planting dates at Pawe. Similarly, variety TGX133-2644 also produced significantly higher yield when planted on 8 June at Debatie and its yields, though decreased due to later plantings, were still higher than the yields of other varieties at other planting dates. Furthermore, Cocker 240 planted on 8 June produced statistically similar yields to TGX 133-2644 planted on 8 June to 8 July.

It may, therefore, be recommended that TGX133-2644 may be planted at 8 June or 23 June for maximum yield at Pawe and Debatie, whereas variety Davis may be planted any time between 8 June and 8 July for maximum yields at Pawe. Furthermore, Cocker 240 or Clark 63K may also be considered for planting in first week of June at Debatie.

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