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Comparison of Nodal Distribution of Soybean Cultivars' Yield Components in Different Planting Dates

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Abstract: Aim of this study was to determine planting date effects on Nodal distribution of yield and its components in nine indeterminate soybean cultivars. To meet such a purpose, a split plot design based on a randomized complete block layout with six planting dates (24th April, 10th and 27th May, 10th and 26th June and 11th July) as main plots and nine cultivars (Williams, Clark 63, SRF 450, Steele, Hark, Corsoy, Blackhawk, Woodworth and Bonus) as sub plots have been used in five replications. The results have clarified that height, branch number, pod number, grain number and seed weight plays an important role on yield increasing. So that, medium maturity cultivars have producing maximum number of pods, grains and seed weight in their upper two third of canopy. Also, various cultivars have indicated different reactions for yield components, so that, Williams and Woodworth (medium maturity cultivars), Steele and Bonus (early maturity cultivars) have produced larger seeds in different planting dates. Generally, Woodworth, in comparison with the other cultivars, demonstrating superiorities in all the considered traits. Maximum amount of pod number, grain number and seed weight in early maturity cultivars was belong to 27th of May planting date, however, for Woodworth and Clark 63 (medium maturity) it was 24th of April and 27th of May, respectively. The highest 100 seed weight per node were produced at 26th of June and 27th of May planting dates by Woodworth and Corsoy, respectively. Differences between planting dates for 100 seed weight in Clark 63 and Bonus were not significant.

Key words: Soybean, Nodal distribution, yield components, planting dates

INTRODUCTION

There are little numbers of published works which are directly correlated with Nodal distribution of soybean (*Glycine max* (L.) Merr.) yield components. Hansen and Shibles (1978) have considered seasonal changes of soybean flowering and podding dates that also includes Nodal distribution of generative parameters. They found that highest number of flowers and pods are formed in middle part of canopy and most of flowers and pods dropping have been occurred in lower nodes. Numerous flowers, pods and grains of soybean are aborted before maturity. Even in optimum growth conditions these losses are common for soybean (Brevedan *et al*., 1978; Mathew *et al*., 2000). However, in unfavorable conditions, environmental stresses cause additional losses of flowers, pods and grain (Carlson *et al*., 1982; Board, 1985; Ball *et al*., 2001). Ramseur *et al*. (1984) believed that reduction of calcium and nitrogen, high temperature (more than 40°C) and moisture stress of soil play negative roles on flower and other organs dropping in soybean. Boedhram *et al*. (2001) found that in corn, nodes have produced various leaf area and according to their position on plant have different contribution for determining ultimate yield.

Delay planting is another important environmental factor that can affect yield and its components of soybean (Anderson and Vasilas, 1985). A number of researchers have studied these relationships and found that yield or yield component's reduction in soybean due to delay planting is depending on cultivar, period length of delaying and climatic conditions during growth season (Anderson and Vasilas, 1985; Board, 1985; Cartter and Hartwig, 1963; Parker *et al*., 1981). However, yet there are a few reports on Nodal distribution of yield and its components in relation to planting dates (Boedhram *et al*., 2001). Koller (1971) has used Gompertz method of analysis of growth stages into the population levels of soybean. Defining relationships between distribution of grain and agronomic practices may influencing factors affecting yield for better prediction of performance (Ramseur *et al*., 1984; Ball *et al*., 2001). Wiebold *et al*. (1981) in their study have reported nodal distribution of grain yield for eleven indeterminate soybean cultivars from maturity groups V to VIII. Carlson *et al*. (1982) have considered vertical distribution of yield and its components in irrigated and non-irrigated conditions and Ramseur *et al*. (1984) have also studied vertical distribution of yield and its components in determinate soybean cultivars regarding to irrigation regimes, row spacing and plant densities. They separate number of pods produced on main stem and branches and have independently considered yield and its components. It has bean shown that pods and grains distribution into the canopy of soybean are under influencing of genotypes (Wiebold *et al*., 1981), planting space (Dominguez and Hume, 1978), irrigation (Carlson *et al*., 1982; Ramseur *et al*., 1984) and several other factors.

The current study was conducted to determine planting date effects on vertical distribution of yield and its components in nine indeterminate soybean cultivars.

MATERIALS AND METHODS

The present experiments have been renewed in 2002 to 2003 in the half tropical research station of northern part of Iran with silt clay soil, generally from order of Aridisol with great groups of Camborthid by special gravity of 1.4 g cm^{-3}, pH = 7.5, field capacity of 22 weight percent and wilting point of 10 weight percent and with mean yearly rainfall of 600 mm and mean yearly temperature equal to 14.5°C. A split plot design based on a randomized complete block layout with six planting dates (24th April, 10th and 27th May, 10th and 26th June and 11th July) as main plots and nine cultivars (Williams, Clark 63, SRF 450, Steele, Hark, Corsoy, Blackhawk, Woodworth and Bonus) as sub plots were used in five replications. Seed bed was prepared with planting space of 90 cm and planted with plant density of 270000 plant per hectare on two sides of hills and in plots with 50 m^2 area (5×10) and has been watered once a week. Prior planting 200 kg ha^{-1} ammonium sulfate and 200 kg ha^{-1} ammonium phosphate chemical fertilizers were used and before starting flowering stage 50 kg ha^{-1} nitrogen was added as ammonium sulfate.

To determine yield components in different planting dates (24th April, 10th May, 10th and 26th June and 11th July in 2003), ten samples were randomly selected. The number of branches, pods, grains from pods were counted and then weigh of grains were also measured. The number of nodes were counted and pod number, grain number and grain weight were separately recorded. With general consideration on all present cultivars, Woodworth and Clark 63 (medium maturity) and Bonus and Corsoy (early maturity) can be selected as superior and inferior cultivars regarding to their seed size, respectively. All figures corresponding to vertical distribution of yield components were drawn based on these four cultivars that illustrating a clear feature of all used cultivars and other cultivars stay in between two ends of these medium and early groups.

RESULTS AND DISCUSSION

Analysis of variance for selected components of grain yield of soybean cultivars in 2003 and their corresponding means are shown in Table 1 and 2, respectively.

Whole plant

Comparison of cultivars: Before any explanation on planting dates effects, it is necessary to consider the reactions of different cultivars corresponding with each yield component. Cultivars are significantly different for number of branches, number of pods, number of grains and grain weight either in whole plant or in main stem which has the most effects on increasing grain yield (Table 1). Woodworth (medium maturity) and Corsoy (early maturity) with 3.52 and 3.47 branches produced the most and Hark with 1.63 branches produced the least number of branches, respectively (Table 1).

Generally, medium maturity cultivars Woodworth, Williams, Clark 63 and SRF 450 either in whole plant or in main stem showed superior than other early cultivars for number of pods, grains and grain weight (Table 1). For height, also the above mentioned medium maturity cultivars were taller than other cultivars and Clark 63 and Williams had the tallest height among medium cultivars. Although separation and grouping of cultivars are conducted based on time necessary from planting to harvest, the trend of yield components can be used as a criterion for grouping of cultivars. By means that cultivars having higher yield components (except branch number and 100 seed weight) are included into medium maturity group but others are included into early maturity group. It can be mentioned that it is not possible to use late

Table 1: Means of branch number and yield components per plant of soybean cultivars (each number is means of two planting dates)*,**

		Pod No.		Grain No.		Grain weight (g)	
Cultivars	Branch No.	Total	Main stem	Total	Main stem	Total	Main stem
Williams	2.43^{bcd}	40.6^{bc}	35.3^{b}	98.2^{c}	85.6^{b}	16.7^{b}	14.6^{b}
Clark 63	2.33^{cd}	36.6^{d}	32.0^{c}	85.5^{d}	78.6^{c}	11.7^{d}	10.6^{d}
SRF 450	2.85^{b}	43.6^{b}	30.9^{cd}	107.6^{b}	79.7^{c}	15.2^{c}	11.7^{c}
Steele	2.15^{d}	35.4^{de}	27.1^{e}	58.1^{g}	45.0^{g}	8.3^{g}	6.4^{g}
Hark	1.63^{c}	32.2^{e}	24.8^{f}	64.5^{f}	50.3^{f}	9.6^{f}	7.5^{f}
Corsoy	3.47^{a}	36.3^{d}	22.3^{g}	77.0^{e}	48.5^{f}	11.2^{de}	7.6^{f}
Blackhawk	2.09^{d}	37.7^{cd}	29.7^{d}	75.2^{e}	59.5^{d}	10.6^{e}	8.5^{e}
Woodworth	3.52^{a}	51.0^{a}	27.9^{a}	122.9^{a}	92.7^{a}	19.4^{a}	14.8^{a}
Bonus	2.67^{bc}	36.1^{d}	36.1^{ef}	78.7^{e}	55.3^{e}	12.0^{d}	8.6^{e*}

*Duncan's test (1%), **Different alphabet superscripts shown significant effects among data within a column

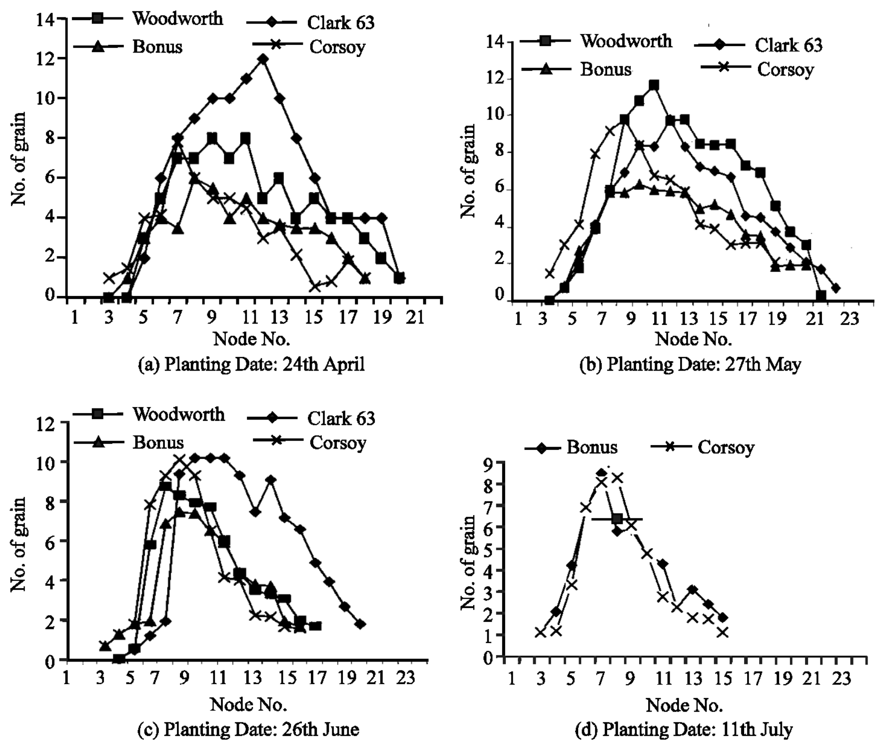

Fig. 1: Nodal distribution of number of grain per node of soybean cultivars

Table 2: Means of grain yield and 100 seed weight of soybean cultivars*,**

Cultivars	Grain yield (kg ha^{-1}) 2002	2003	100 seed weight (g)
Williams	2723.1^{b}	2720.9^{ab}	14.51^{a}
Clark 63	2777.1^{ab}	2774.3^{a}	13.52^{bc}
SRF 450	2633.6^{bc}	2642.1^{bc}	13.20^{bc}
Steele	2291.6^{e}	2362.3^{e}	13.52^{bc}
Hark	2504.0^{d}	2492.7^{d}	13.43^{bc}
Corsoy	2557.3c^{d}	2551.0^{cd}	13.03^{c}
Blackhawk	2135.8^{f}	2153.8^{f}	13.34^{bc}
Woodworth	2819.6^{a}	2831.4^{a}	14.57^{a}
Bonus	2543.9^{cd}	2549.8^{cd}	13.78^{b*}

*Duncan's test (1%), **Different alphabet superscripts shown significant effects among data within a column

maturity cultivars in central part of Iran, because of autumn coldness and production of unfavorable grain yield. This trend is not true for 100 seed weight. As it is illustrated there is significant differences among soybean cultivars for 100 seed weight ($p<0.01$, Table 2). Woodworth and Williams with 14.47 and 14.51 g had the highest and Corsoy (early) with 13.03 g had the lowest 100 seed weight, respectively and the rest cultivars were stayed between these two ends (Table 2). Although, the highest and the lowest 100 seed weight were belong to medium and early maturity cultivars, respectively. There is not a general trend for larger grains of medium cultivars compared to early cultivars and cultivars are different for seed size. For instance, early cultivars Bonus and Steele have larger grains than medium cultivars Clark 63 and SRF 450 (Table 2). For such a reason 100 seed weight can not be used as a criterion for grouping cultivars.

Comparison of planting dates: Effects of planting dates on branch formation was not significant but on number of pods and grains and grain weight either in whole plant or in main stem were significant ($p<0.01$, Table 1). There is no significant difference between planting dates but in number of pods and grains and grain weight there are highly significant differences ($p<0.01$) and planting date of 27th May was superior than other planting dates, while in 100 seed weight, planting dates 10th June and 27th May showed highest 100 seed weight, respectively (Table 3). Generally, planting dates of 27th May and 10th June were suitable for medium cultivars and in later planting dates it would be better to use early maturity cultivars. The reason behind suitability of these planting dates is laid under suitability of cold days of September with podding stage that formation and filling of grains will occur during cold days of September and October (Fig. 1).

Genotype by environment interactions: Interactions between cultivars×planting dates for number of branches, pods and grains, grain weight and 100 seed weight were highly significant ($p<0.01$, Table 1 and 2). In spite of non significant effects of planting dates on number of branches, significant interaction of cultivar×planting

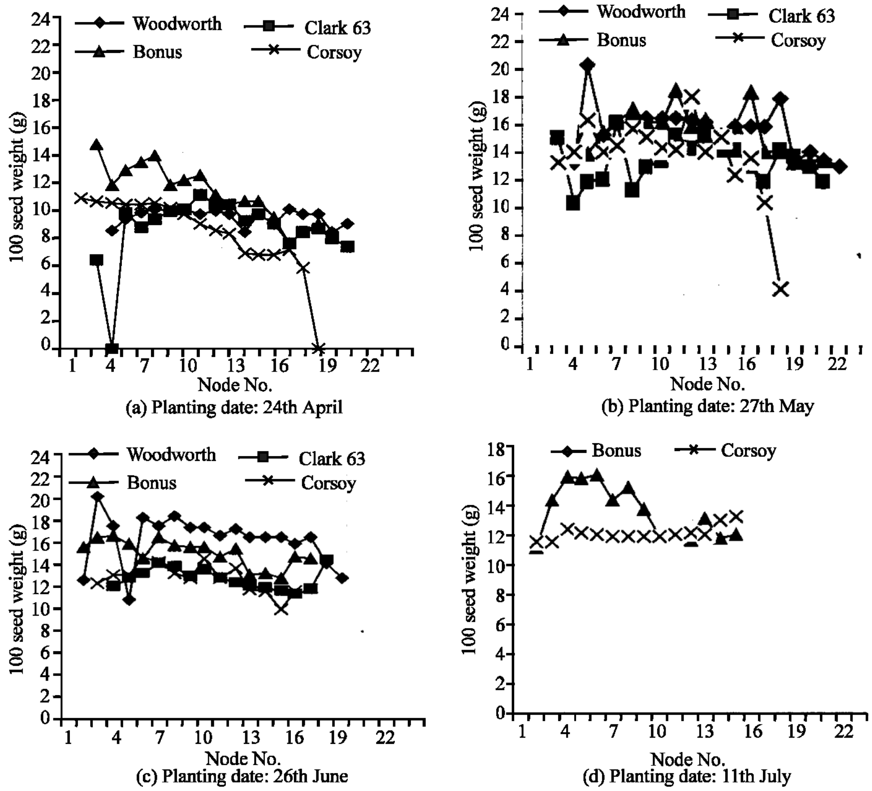

Fig. 2: Nodal distribution of 100 seed weight per node of soybean cultivars

Table 3: Means of yield and yield components of soybean cultivars in different planting dates*,**

	Yield (kg ha^{-1})		100 seed weight (g)	Pod No.		Grain No.		Grain weight (g)	
Planting date	2002	2003	2003	Total	Main stem	Total	Main stem	Total	Main stem
24th April	2531.3[b]	2588.9[a]	12.64[c]	37.4[b]	29.3[b]	80.4[b]	64.9[b]	10.9[b]	8.8[b]
10th May	2348.7[c]	2343.4[b]	12.41[c]	-	-	-	-	-	-
27th May	2562.8[b]	2555.0[a]	14.29[ab]	44.8[a]	34.0[a]	98.0[a]	75.7[a]	15.5[a]	12.1[a]
10th June	2670.3[a]	2660.8[a]	14.82[a]	-	-	-	-	-	-
26th June	2657.0[a]	2663.1[a]	14.11[b]	34.4[c]	25.1[c]	77.8[b]	58.4[c]	11.9[b]	9.2[b*]

*Duncan's test (1%), **Different alphabet superscripts shown significant effects among data within a column

dates showed that various cultivars response differently. In case of other yield components the same problems are illustrated, means that for each planting dates a special cultivar can be chosen, in which this case is mostly correlated with ranking genotype and its genetic potential.

Vertical distribution: Soybean yield is under influence of its components in which the most important components are number of nodes, height, number of branches, pods and grains and grain weight. Photosynthesis rates of each cultivar is correlated with its morphology and regional climatic conditions. For morphological instance a cultivar can produce more Net Assimilation Rate (NAR) when more light can penetrate into the canopy and use maximum light for photosynthesis (Koller, 1971; Hansen and Shibles, 1978; Mathew *et al*., 2000). The more levels of leave exhibited in solar radiation, the more NAR will be produced when all other conditions are fixed (Anderson and Vasilas, 1985). Therefore, plant for receiving heterogeneous light energy in different part of canopy on one hand and various rate of leave levels in different nodes on the other hand, (For number, density and angle of leaves with solar radiation and ultimately rate of light received by leaves of each node), shows numerous diversities in yield components in different nodes.

Comparison of cultivars: As it is expected because of existence of genetic and morphological variations, number of pods and grains and grain weight of cultivars are variously distributed throughout canopy (Carlson *et al*., 1982). Maximum rates of mentioned variables are often stayed around middle nodes (Fig. 1-3). In planting 24th

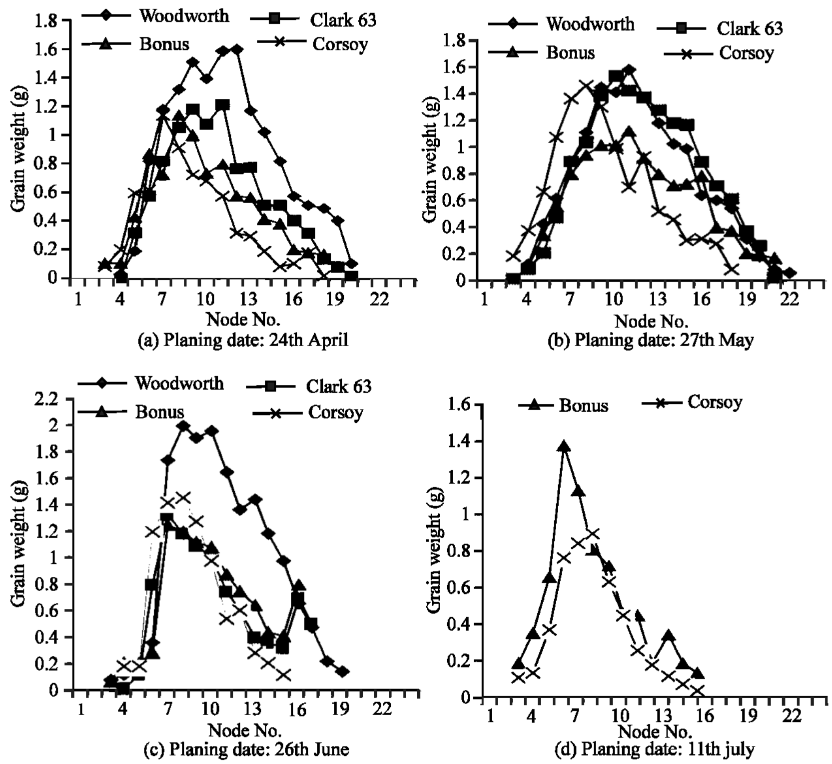

Fig. 3: Nodal distribution of grain weight per node of soybean cultivars

April medium maturity cultivars Woodworth and Clark 63 showed considerable superiority especially in upper nodes in comparison with early maturity cultivars Bonus and Corsoy for number of grains (Dominguez and Hume, 1978). Only in lower nodes Corsoy showed a little superiority (Fig. 1A). In this planting date maximum grain number production is belong to node number 12 of Woodworth. In planting 27th May Clark 63 produced more number of grains than Woodworth and the trend of Corsoys superiority in lower nodes is also continued in this date of planting. The similar results with other cultivars are shown by Ramseur *et al*. (1984). However, in upper nodes the number of grains will severely reduced, while reduction severity of grain number in upper nodes in Clark 63, Woodworth and Bonus were much lesser than Corsoy, respectively (Fig. 1b).

In planting date 26th June, the superiority of medium cultivars for grain number in comparison with early cultivars is steel continuing. Only in Woodworth, increasing severity in grain number of lower nodes (up to 8th node) was lessen. However, middle nodes produced most grain numbers and its reduction in upper nodes showed a smooth trend. However, Corsoy with more number of grains in lower nodes, showed very many severe reduction for grain number in upper two third part of canopy. Varieties Clark 63 and Bonus have been stayed at these two ends, respectively (Fig. 1c). Ultimately, in planting 11th July medium cultivars have not produced good yield and early cultivars have also produced very many lesser yield from previous planting dates. There was no serious difference between Corsoy and Bonus in this planting date (Fig. 1d).

Bonus (early) showed superiority for 100 seed weight compared to all other tested cultivars in two third lower part of canopy in 24th April planting, however, Woodworth showed superior than Bonus in upper nodes. Corsoy showed superiority in half lower part of canopy but after Bonus, however, its 100 seed weight has severely reduced in upper nodes and produced much smaller seeds than medium maturity cultivars (Fig. 2a). Bonus and Woodworth produced larger seeds than Clark 63 and Corsoy in 27th May planting. There is not much differences in seed size between Bonus and Woodworth and also between Clark 63 and Corsoy in different nodes (Fig. 2b). Woodworth produced larger seeds from Bonus in 26th June planting but there is no differences between Clark 63 and Corsoy for production of small seeds. Therefore, they showed lesser 100 seed weight than Woodworth and Bonus in various nodes (Fig. 2c). Bonus produces much more 100 seed weight than Corsoy in various nodes in 11th July planting (Fig. 2d).

For grain weight per node there was a similarity with trend and ranking of grain number of tested cultivars in 24th April planting, but it seems that producing larger

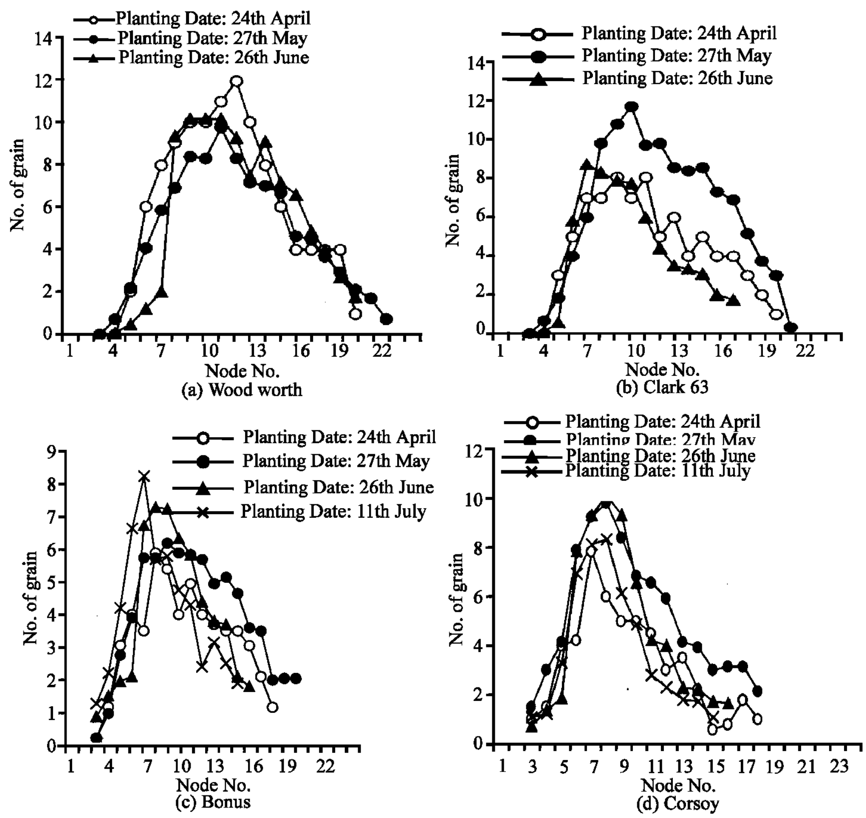

Fig. 4: Nodal distribution of number of grain per node of soybean cultivars in different planting dates

seeds by Woodworth, make severe difference between this genotype with all other tested cultivars (Fig. 3a). This figure showed itself much more obviously in later plantings (Workneh *et al*., 1998; Garner and Allard, 1930; Cartter and Hatwig, 1963), so that Clark 63 which had considerable superiority in grain number than Woodworth in 27th May planting, showed little difference for grain weight per node and even up to 11th node was a little lower than Woodworth (Fig. 3b). It means that Woodworth and Bonus genotypes having lesser grain number than Corsoy and Clark 63 cultivars in 8 lower nodes. However, for grain weight the trend of differences have been reduced and Woodworth got more difference than other cultivars in 7th node. The severe differences have been happened in nodes near to middle part of canopy. Bonus which is illustrating weaker than Clark 63 for grain number, showed smoothly superiority for grain weight in planting 26th June. Therefore, larger seed size in this planting date cause superiority in favor of Bonus compared to Clark 63 (Fig. 3c). Finally, in planting 11th July that there was not considerable difference between Bonus and Corsoy for grain number, for mentioned reason Bonus has showed considerable superiority for grain weight per node compared to Corsoy (Fig. 3d). This point has also clearly been shown in Table 1 that generally Woodworth has produced heavier seeds than other cultivars either on main stem or on whole plant. Corsoy showed briefly weaker than other cultivars in grain weight, but Woodworth showed superiority for grain number and Corsoy and Bonus were weaker than other cultivars. Table 2 has fully shown the mentioned theory because of undoubted superiority of Woodworth for 100 seed weight and producing larger seed size by Bonus compared to Clark 63 and producing small seed size by Corsoy is obviously illustrated.

Planting dates comparisons: Pod and grain number, grain weight and 100 seed weight of soybean cultivars in different planting dates are distributed variously throughout canopy because of variety environmental conditions, including temperature and photoperiods (Garner and Allard, 1930; Hansen and Shibles, 1978; Weibold *et al*., 1981). Maximum amounts of mentioned variables stayed at middle part nodes (Fig. 4-6). Woodworth produces its maximum and minimum number of grain in different nodes in 24th April and 27th May planting dates, respectively. In Clark 63 maximum and minimum grain number production were correlated with

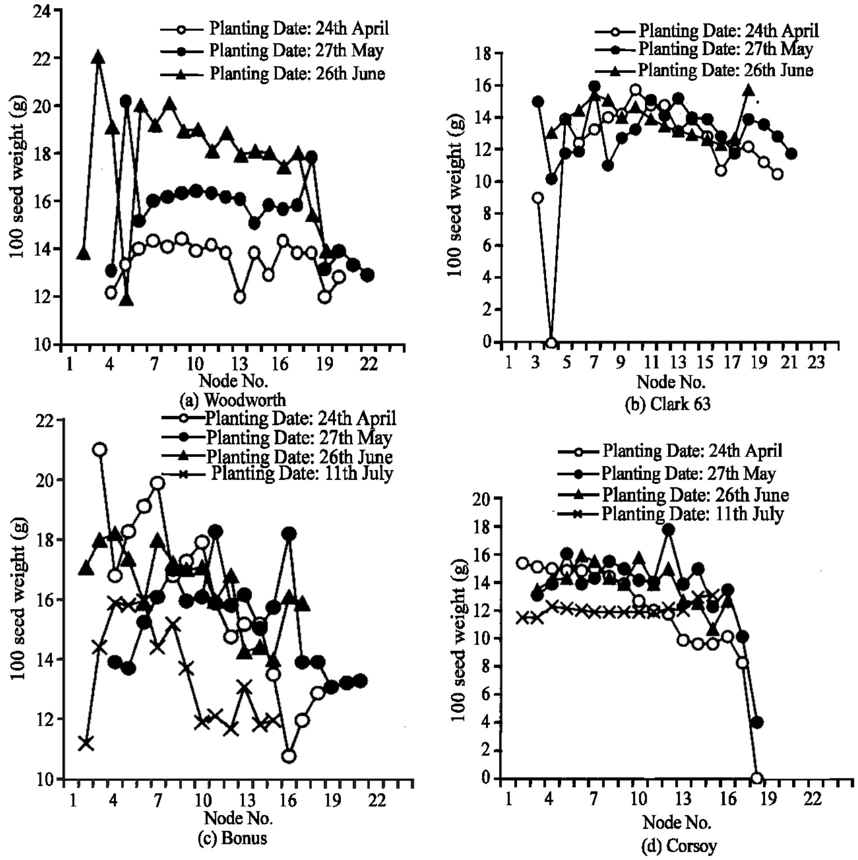

Fig. 5: Nodal distribution of 100 seed weight per node of soybean cultivars in different planting dates

27th May and 26th June, respectively. Maximum grain number production in both Woodworth and Clark 63 was belong to upper two third part of canopy in all planting dates (Fig. 4a and b). Bonus and Corsoy have produced maximum and minimum grain number in 27th May and 11th July planting dates, respectively (Board, 1985; Brevedan *et al*., 1978). Maximum grain number in each cultivar was correlated with half lower part of canopy in whole planting dates and 11th July planting has created more grain number in Bonus than other planting dates (Fig. 4c and d).

Woodworth in 26th June planting date produced maximum 100 seed weight in different nodes, means that the largest and heaviest seeds have been produced by this planting date, however, 27th May planting date introduced medium size seeds (Fig. 5a). Different planting dates have not shown serious differences for 100 seed weight in Clark 63 (Fig. 5b). Planting dates 24th April, 27th May and 26th June have not many differences in Bonus for 100 seed weight, while planting 11th July in comparison with previous dates of planting produced lighter 100 seed weight (Fig. 5c). Finally, Corsoy has produced maximum and minimum 100 seed weight in 27th May and 11th July planting dates, respectively (Fig. 5d).

In term of grain weight, Woodworth in 26th June, Clark 63 in 27th May, Bonus in 11th July for lower part nodes and in 27th May in upper part nodes and finally Corsoy in 27th May were superior than other planting dates, respectively. In Woodworth although the differences is serious for grain weight, there is no differences in 24th April and 26th June planting dates from 7th to 10th nodes. This may shows that these nodes have provided the largest seeds in all planting dates in Woodworth cultivar. So that, at these nodes larger seed size have been produced in planting date 26th June (Fig. 6a). The trend of grain weight distribution on various nodes was often similar to that of grain number in Clark 63 (Fig. 6b). Bonus has similar trend, but with a little larger seeds than that of Clark 63, because difference between grain weight in various planting dates of Bonus compared to grain number is a little more than that of Clark 63 (Fig. 6c). Finally, Corsoy showed similar trend to that of Bonus and probably this cultivar produces larger seeds in plantings 27th May and 26th June than other planting

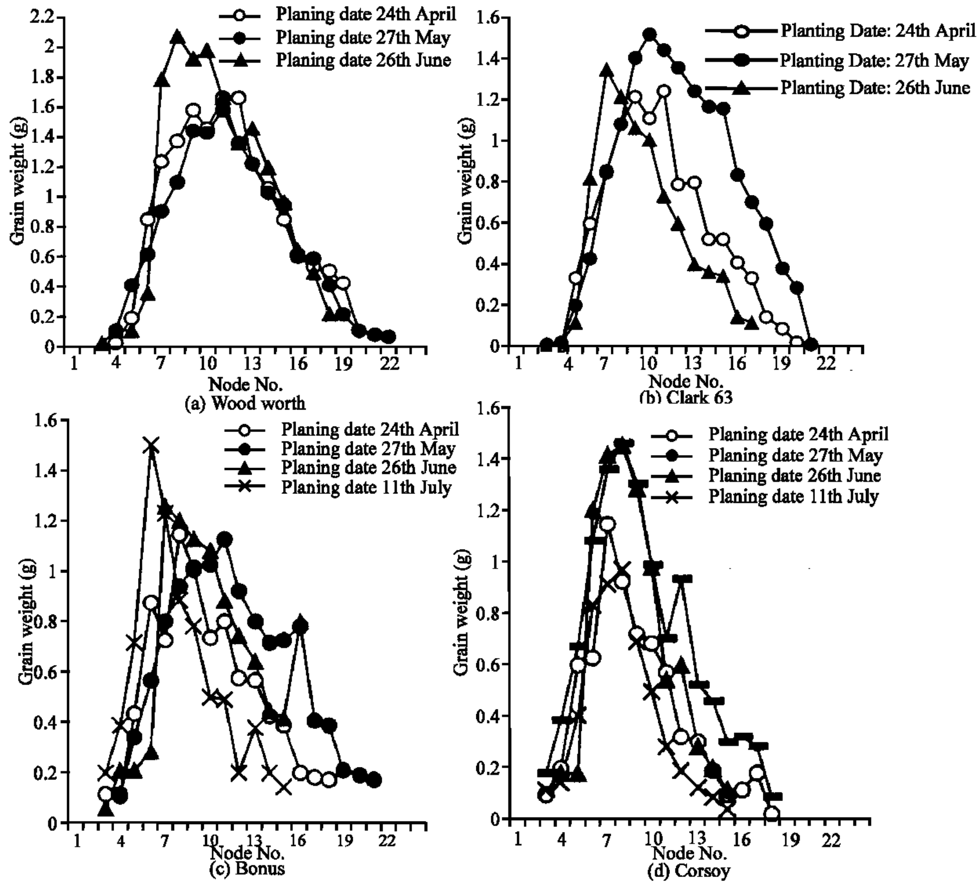

Fig. 6: Nodal distribution of grain weight per node of soybean cultivars in different planting dates

dates (Fig. 6d). Table 3 indicates significant differences among 27th and other planting dates for grain weight either in main stem or in whole plant. Also, for 100 seed weight plantings 10th June and 27th May are superior than other planting dates, respectively.

CONCLUSIONS

The pod and grain number, grain weight and 100 seed weight of soybean are distributed variously on different nodes so that the highest amount of each mentioned variables are produced in middle parts of canopy (Boedhram *et al*., 2001). Generally, maximum amount of mentioned variables have been produced in two third of upper and half of lower part of canopy in medium and early maturity cultivars, respectively (Carlson *et al*., 1982; Ball *et al*., 2001). The medium and early maturity cultivars can be differentiated obviously for pod and grain number and grain weight but grain weight is not a good criterion for this purpose. All the considered variables play effective role in grain yield production of all cultivars. In most cultivars most of pod and grain number and grain weight have been created in 27th May planting date, but Woodworth and Corsoy showed maximum 100 seed weight per node in 26th June and 27th May planting dates, respectively and there were no significant differences among various plantings for Clark 63 and Bonus.

Results showed that it may be possible to produce soybean as a second crop using late planting dates of early maturity cultivars in conditions like this experiment, even after harvest of wheat. As it is previously expressed, medium maturity cultivars may be grown in planting dates of late April to early June, however, it can not be recommended for planting dates after late June. Most of results of current study is in accordance with Carlson *et al*. (1982). In terms of adaptability and stability of cultivars (Ball *et al*., 2001) in regional conditions of present work, Woodworth (medium) and Bonus (early) have shown more adaptability and more stability than other cultivars. There are better conditions for state of yield components production in various planting dates for these two cultivars. For producing of higher NAR, if other agronomic and climatic conditions are optimum, light penetration throughout the canopy would have the most influences. Middle part nodes showed the most suitable reaction in all cultivars and planting dates. For this reason, it can be recommended that works may continued on definition ideal type of plant through plant breeding and biotechnological methodologies and efforts should be done for increasing the node contribution in final yield production.

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