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# Effects of Fertilizer, Inoculation and Sowing Time on Growth, Yield and Yield Attributes of Soybean under Field Conditions

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**Abstract**: Two year field experiments on two different sowing dates in response to various level of added fertilizer on various growth, yield and yield attributes of soybean CV. Williams-82 was conducted in medium textured salt free soil of Quetta. Fertilizer treatments were comprised of one level ($T_2$) of $P_2O_5$ + $K_2O$ fertilizer @ 60 + 30 kg $ha^{-1}$ and five level ($T_3$ - $T_7$) of N fertilizer @ 25, 50, 75, 100 and 120 kg $ha^{-1}$ plus the same constant dose of P and K respectively. These six fertilizer levels were applied to both non-inoculated (non-inoc) and inoculated (inoc) crop. Results showed that nodules were found absent in any set of experiment, which could be attributed to either sufficient level of soil $NO_3$ or deficient level of total Fe and Cu or might be due to any other edaphic/climatic factor(s). Results also showed that fertilizer level generally exhibited significant positive influence on growth parameters (except middle leaflet area) of early plantings (EP), but reverse was true for late plantings (LP). While inoculation effects were noted as significant for both plantings (BP). Results further indicated that fertilizer level had slightly ($P<0.05$) to highly significantly ($P<0.01$) increased the grain yield of BP respectively, but this increase was much more prominent in EP than LP. A maximum yield (i.e., 3509 kg $ha^{-1}$ and 2604 kg $ha^{-1}$) was obtained in $T_6$ non-inoc and $T_6$ inoc of EP and LP respectively. Results also revealed that the response of yield attributes in relation to added fertilizer were found highly significant in EP and non-significant in LP (except 100 seed weight). The same was true for inoculation studies (except sterile pods and pods contained 4 beans). It was also concluded that most of the yield attributes of BP exhibited highly significant positive correlation with their yield, which could be used a suitable selection criteria for predicting the grain yield in soybean cv.Williams-82. However, growth parameters exhibited non-significant association with the yield of both sowing dates.

**Key words:** Soybean, fertilizer, inoculation, sowing, nodules, growth, yield, correlation

## Introduction

Soybean belongs to family leguminosae, sub-family papilionoidae and genus glycine. The cultivated form is [*Glycine max* (L.) Merill]. Legumes are grown on 1.9% of the total cultivated land of Pakistan, out of which soybean is cultivated on 0.23% of the total legume by taking 8th position. Soybean is now getting popularity among the farming community of the country on account of its high protein, oil contents and high inputs responsiveness under irrigated conditions (Ayub *et al.*, 1998 and Aslam *et al.*, 2000). The national average yield of five years is very low (689 kg $ha^{-1}$) as compared to potential yields i.e., 4200 kg $ha^{-1}$ (Anonymous, 1996). It is generally believed that low yield in farmers fields are due to lack of awareness about the recommended production technology adopted by the growers.

In Balochistan province, a large area is lying as wastelands, which are covering an area in million of hectares. Moisture shortage, soil erosion and low fertility etc., are the main ecological constraints, which limits the crop as well as rangeland developments in this huge area (Anees, 1980). Leguminous plants in association with *Rhizobium* species have the potential to fix large amounts of atmospheric $N_2$ which contributes to the soil N pool provided that the $N_2$ fixation is not restricted by other environmental or microbial factors (Jefing *et al.*, 1992; Ali and Hussain, 1996). In Pakistan soils have either nil or very low viable count of effective rhizobia and low N-supplying capacity because of low organic matter (0.3-1.0%) levels (Ladha *et al.*, 1996) and approximately 1.0% of the total legume crops are inoculated (Aslam *et al.*, 1997 and 2000).

Planting time, row spacing, temperature and irrigation also influenced the yield, protein and oil contents of soybean seed. Research revealed that planting time significantly influenced the plant height, yield $ha^{-1}$, 100 seed weight, seed size, number of pods $plant^{-1}$ and number of pods contained 1, 2, 3, and 4 beans (Lathwell and Evans, 1951; Ehsanullah *et al.*, 1989; Shah and Hatam, 1989). Most of the researchers are of the opinion that June is the best sowing date for most of the soybean cultivars. However, such dates are vary in different ecological zones and maturity group of the crop.

For improvement of yield, the information on direct and indirect effects of yield attributes provides realistic basis for a successful breeding program. Katiyar and Singh (1990) observed that pods $plant^{-1}$ was positively and significantly correlated with grain yield of faba beans. Zahoor and Ashiq (1992) concluded that yield $plant^{-1}$ was positively and significantly associated with pod $bunch^{-1}$, seed $pod^{-1}$ and 100 seed weight of rice bean. While Khan *et al.* (2000) reported that seed yield exhibited significant and positive correlation with all yield contributing attributes of soybean (except pod height).

The study was therefore, aimed to evaluate the beneficial effect of various levels of fertilizer alone and also in combination with inoculum (seed inoculation) on nodulation, growth, yield and yield attributes of field grown soybean at two different sowing dates. The study was also initiated to furnish the information on the nature of association among different yield attributes to choose a suitable selection criteria for predicting the grain yield in soybean.

## Materials and Methods

Two year field experiments on soybean *Glycine max* L. Merill CV. Williams-82 at two different sowing dates were carried out during (Kharif season) the 1st week of July, 1996 (late sowing) and June, 1997 (early sowing) in Agricultural Research Institute (ARI), Quetta, respectively. Seven different treatments (T) of fertilizer were applied to both non-inoculated and inoculated set of experiments.

$T_1$ was kept as control (check); $T_2$ contained 60 and 30 kg $P_2O_5$ $ha^{-1}$ and $K_2O$ Kg $ha^{-1}$, respectively. Whereas, from $T_3$ - $T_7$, N-fertilizer was added @ 25, 50, 75, 100 and 125 kg $ha^{-1}$ along with combination of the same constant dose of P and K, respectively. The urea, diammonium phosphate (DAP) and sulphate of potash (SOP) was used as a source of N, P and K, fertilizer respectively. A full dose of DAP, SOP and half dose of urea was broadcasted at the time of sowing. Whereas, the remaining half dose of urea was also broadcasted to the respective plots but two weeks after thinning. Plots were divided into two sets i.e., one for fertilizer without inoculum (non-inoc) and other for fertilizer with inoculum (inoc). The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications each. The plot size was 2.25 × 5.00 $m^2$ and 2.50 × 2.50 $m^2$ for the growing year, 1996 and 1997, respectively. Seeds were drilled in rows 40cm apart by single coutler hand driven drill @ 80 kg $ha^{-1}$

and inoculum viz., *Rhizobium japonicum* strain SL2 was applied to the seed @ 8.0g $kg^{-1}$ seeds (Anonymous, 1984). Before application, the inoculum was cultured in YEM broth medium following the procedure of EvaTas *et al.* (1996) and the viable count was found as $10^6$ to $10^7$ $g^{-1}$ inoculant.

For morphological/agronomic and reproductive traits, the plants were harvested during the course of experimental studies at various growth interval of days/weeks after sowing (DAS, WAS). Three plants from each plot were carefully uprooted at different stages of growth i.e., 25, 35 and 45 days for their nodulation studies. Another set of three plants of 70 days were also studied for the measurement of middle leaflet area of trifoliate No. 5, 6, 7 and 8 (on main stem from bottom to top) and then the average of all these were calculated. While another set of eight plants was also randomly selected at 75 days for the measurement of petiole length (cm) and plant height (cm $plant^{-1}$). The final destructive harvest was carried out when the plants of all treatments attained their physiological maturity with complete senescence of leaves and yellow brown coloration.

The following yield and yield attributes were finally recorded:-

Grain yields $plot^{-1}$ (kg), (2) grain yields $ha^{-1}$(kg), (3) 100 seed weight (g), (4) total number of pod $plant^{-1}$, (5) number of empty (sterile) pod $plant^{-1}$, (6) number of 1 seeded pods $plant^{-1}$, (7) number of 2 seeded pods $plant^{-1}$ (8), number of 3 seeded pod $plant^{-1}$ and (9) number of 4 seeded pod $plant^{-1}$.

Before sowing a composite soil sample (0.0-45cm depth) was taken and analyzed for their physicochemical characteristics (Anonymous, 1953). The soil of the study area was found medium textured (clayey loam), basic in reaction, salt free, low organic matter, Na and K and with medium Ca and Mg contents. While water used for irrigation was fresh and normal with adequate amount of ions viz., Na, Ca, Mg and Cl (Table 1). Field soil was also tested for their native rhizobia, which were found absent. The data obtained were statistically calculated following the procedure described by Steel and Torrie (1980). MSTAT-C Computer software package for statistical analyses was used for calculation of analyses of variance (ANOVA). Simple correlation coefficient (r) studies were also worked out for all mentioned parameters following the procedure reported by Fisher and Yates (1953).

## Results and Discussion

**Nodulation:** Nodule plays a significant role in growth, yield, yield attributes and various biochemical compositions of soybean seeds. But unfortunately they were formed neither in any dose of fertilizer alone (even in control), nor in combination with satisfactory viable count of *Rhizobium japonicum* strain SL2 (i.e., $0.44 \times 10^7$ counts $g^{-1}$ carrier). Nodule formation is controlled by many climatic and edaphic factors. Even though our soil and water pH, water holding capacity, electrical conductivity (EC), total soluble salts (TSS), soil texture and viable count of rhizobia of inoculum were satisfactory (Table 1), but still nodules were not established. Research revealed that adequate level of $NO_3$ application (2.0 mM to 5.0 mM) adversely affect the root isoflavonoid concentration and markedly affect the induction of nod genes in rhizobia and nodule development in hypernodulated soybean cv.Williams-82, resulted in greater inhibition of $N_2$ fixing enzyme (nitrogenase) activity. Soybean CV. Williams-82 is a $NO_3$ sensitive mutant and it's failure in term of nodulation could be mainly attributed to high concentration of soil $NO_3$ contents (i.e., 5.20 mM), which led $N_2$ fixation, resulting decrease supply of energy from host to the bacteroids. Our findings regarding deceiving nodulation is strongly in conformity with the results achieved by many earlier researchers (Cho and Harper, 1991 and 1993; Serraj *et al.*, 1992; Arriagada *et al.*, 1993; Achakzai and Kayani, 2002). Moreover, soybean is a symbiotic leguminous crop and Fe is a major constituent of the red leghaemoglobin in the nodules, which protects nitrogen-fixing enzyme (nitrogenase) from oxygen inactivation. The non-appearance of nodules could be due to Fe deficiency of soil and irrigation water as explained by Tandon (1993) and Anonymous (1984 and 1999). In the present study Cu content of soil and water was found lower than the detection limits (Table 1). Researchers have also reported that Cu is possibly required for symbiotic $N_2$ fixation (Tandon, 1993; Anonymous, 1999). Therefore, the non-appearance of nodules might also be due to Cu deficiency. However, the exact role of Cu in nodulation is not yet understood. There are other climatic factors like evapotranspiration and relative humidity, which might have contributed to this differential response towards inoculation. This is generally observed in Pakistan and particularly in Balochistan that leguminous crop often failed to produce nodules. Therefore, it can be safely concluded that deceiving nodulation might be due to sufficient level of soil $NO_3$ or deficient level of Fe and Cu or any other ecological factor(s). Much more efforts needs to be focussed over deceiving nodulation to pinpoint the exact edaphic or climatic factor(s), which generally limits nodulation in legumes and particularly in soybean crop.

**Growth:** Fertilizer treatments exhibited significant influence on growth parameters (except middle leaflet area) of early plantings (EP) (Table 2). While reverse was true for late plantings (LP). The inoculation effect in general was also statistically found significant for both planting dates, but reverse was true for interaction between fertilizer and inoculum.

Data regarding mean separation values (Table 3a) showed that in response to various fertilizer treatments, the petiole length of EP was significantly and positively influenced (except $T_7$) when compared with check ($T_1$). But among various doses of fertilizer such effects were statistically found non-significant. However, in case of LP fertilizer doses showed either adverse effect or non-significant effect on this parameter. A similar response was also noted by Achakzai and Kayani (2002) in pot culture studies of soybean grown on the same date. Results also showed that maximum petiole length was noted in $T_3$ and $T_6$ doses of fertilizer for EP and LP, respectively. Results further demonstrated that by comparing inoculated with non inoculated in particular doses of fertilizer, inoculation significantly and positively affected the petiole length of EP but non-significantly in LP (except $T_4$). Achakzai and Kayani (2002) also reported the same. However, on the basis of marginal mean values, the inoculation effect was recorded as 14.95 and 10.08% greater in EP and LP, when compared with their respective non-inoc treatments. In present studies even though nodules were formed neither in inoculated nor in non inoculated, but such positive response of inoculation suggests that rhizobia might have initially infected the cortical region of root but could not multiply properly. Data further suggests that by comparing the grand mean value of both plantings, EP produced 29.19% greater petiole length over LP, which signifies the role of early sowings.

Data pertaining to mean separation values (Table 3a) showed that in response to various level of added fertilizer, the middle leaflet area remained unaffected in both planting dates. However, among fertilizer doses $T_3$ and $T_4$ mathematically produced better results in EP and LP respectively. On the contrary Akhtar *et al.* (1988) reported that soybean crop fertilized with NPK produced more leaf area. While Achakzai and Kayani (2002) noted that higher doses of N fertilizer produced more leaflet area in pot culture soybean. Results also showed that by comparing the inoculated with non inoculated treatments in particular doses of fertilizer, inoculation particularly showed non-significant effect in LP and generally in EP (except $T_2$ and $T_?$). However, on the basis of marginal mean values, the inoculation effect was noted as 3.80% greater and 0.26% lesser in EP and LP as compared with non-inoc experiments respectively. While on the basis of grand mean values, EP produced 70.11% greater leaflet area over LP. This signifies the importance of early sowings and is strongly in agreement with the results of Hatam and Jamro (1989).

Data regarding mean separation values (Table 3a) showed that in response to different level of added fertilizer, the plant height of LP was statistically non-significant. While in case of EP each treatment showed significant positive effect as compared with

**Table 1: Physicochemical characteristics of soil and water samples used for the study of two-year field grown soybean cv.Williams-82**

| | Physical characteristics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Samples** | **TSS (ppm)** | **pH** | **$Ec_e$ (mS $cm^{-1}$)** | **Organic matter (%)** | **Water holding capacity (%)** | **Sand (%)** | **Silt (%)** | **Clay (%)** | **Textural class** |
| **Soil** | 2000 | 8.2 | 3.08 | 0.78 | 38.55 | 22.66 | 49.00 | 28.33 | Clay loam |
| **CFC** | - | *Basic | *Salt free | *Low | Medium | - | - | - | **Mediumtextured |
| **Water** | 422 | 7.6 | 0.65 | - | - | - | - | - | - |
| **CFC** | *Fresh (Non-saline) | *Normal | *Normal | - | - | - | - | - | - |

| | Chemical characteristics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Na meq ($L^{-1}$)** | **K meq ($L^{-1}$)** | **Ca meq ($L^{-1}$)** | **Mg meq ($L^{-1}$)** | **Cl meq ($L^{-1}$)** | **$NO_3$ (mM)** | **$NH_4$ (mM)** | **$NO_2$ (mM)** | **$PO_4$ (ppm)** | **Cu (ppm)** | **Fe (ppm)** |
| **Soil** | 6.98 | 0.46 | 15.13 | 22.73 | 25.00 | 5.20 | 3.26 | 0.17 | 168 | ND | 11.7 |
| **CFC** | *Low | *Low | *Medium | *Medium | **Saline | - | - | - | - | - | - |
| **Water** | 2.93 | 0.04 | 02.67 | 07.68 | 00.41 | 0.43 | ND | 0.02 | 58.33 | ND | 03.14 |
| **CFC** | ***Good | - | ***Good | ***Good | ***Good | - | - | - | - | - | - |

**CFC = categories for classification; ND = Not detected; *and ** following the soil classification of Kayani and Sheikh (1981) and Anonymous (1953 respectively; *, ** and *** Followed the water classification of Hem (1973), Anonymous (1953) and Davis and DeWiest (1966) respectively**

Table 2: Analysis of variance (ANOVA) for growth, yield and yield attributes of field grown soybean (*Glycine max* L.) Merill cv.Williams-82 at two different sowing dates in response to fertilizer treatments alone (A) and in combination with inoculum (B)

| | Mean square for fertilizer (A) | | Mean square for inoculum (B) | | F.value of variables at an error of 26: Fertilizer (A) (Df = 6) | | Inoculum (B) (Df = 1) | | A x B (Df = 6) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variables | LP | EP | LP | EP | LP | EP | LP | EP | LP (NS) | EP |
| 1 | 0.734 | 2.530 | 16.519 | 68.838 | 0.6092NS | 0003.4348* | 13.7166** | 0093.4649** | 1.4687 | 0000.8456NS |
| 2 | 5686.800 | 3870.600 | 15.192 | 9164.200 | 1.0914NS | 0001.9377NS | 00.0029NS | 0004.5878* | 0.8067 | 0003.1822* |
| 3 | 12.160 | 49.471 | 136.770 | 177.450 | 1.1329NS | 0004.4176** | 12.8546** | 0015.8455** | 1.6202 | 0001.4720NS |
| 4 | 590.840 | 421.360 | 17385.000 | 1.205 | 2.5539* | 0719.268** | 07.5146* | 0002.057NS | 0.8608 | 0003.606** |
| 5 | 467140.200 | 1079400.600 | 1373790.900 | 2983.700 | 2.5547* | 0714.501** | 07.5131* | 0001.9750NS | 0.8612 | 0003.5639* |
| 6 | 2.312 | 1.991 | 1.047 | 3.994 | 3.5614* | 0321.074** | 01.6119NS | 0641.068** | 0.9034 | 0007.648** |
| 7 | 270.277 | 96.631 | 331.973 | 36.159 | 1.3769NS | 0495.682** | 01.6912NS | 0185.4795** | 0.7978 | 0003.4981* |
| 8 | 1.501 | 0.209 | 12.628 | 1.170 | 1.2365NS | 0025.855** | 10.405** | 14485.8** | 0.7216 | 1023.73** |
| 9 | 6.880 | 1.251 | 2.546 | 7.077 | 0.9570NS | 1412.04** | 00.3541NS | 7984.75** | 1.5111 | 1085.90** |
| 10 | 11.529 | 20.891 | 4.882 | 23.926 | 0.7244NS | 1324.83** | 00.3068NS | 1517.27** | 1.0719 | 0547.42** |
| 11 | 110.080 | 38.811 | 72.812 | 97.037 | 1.7848NS | 0525.29** | 01.1805NS | 1313.34** | 0.4445 | 0232.29** |
| 12 | 0.339 | 0.193 | 2.453 | 2.585 | 0.8027NS | 1438.15** | 05.8133* | 19256.4** | 0.2048 | 1749.42** |

*and** significant at P< 0.05 and P< 0.01 respectively. NS = non-significant. LP = late planting on July, 1996 and EP = early planting on June, 1997. Df = degree of freedom. (1) Petiole length, cm. (2) Middle leaflet area, $cm^2$. (3) Plant height, cm. (4) Yield $plot^{-1}$, kg. (5) Yield $ha^{-1}$, kg. (6) 100 seed weight, g. (7) Total number of pod $plant^{-1}$. (8) Number of pods contained no bean. (9) Number of pods contained 1 bean. (10) Number of pods contained 2 beans. (11) Number of pods contained 3 beans. (12) Number of pods contained 4 beans.

**Table 3a: Effect of various levels of fertilizer without inoculum (non-inoc) and with inoculum (inoc) on growth and yield of field-grown soybean (*Glycine max L.)* Merill cv.Williams-82 at two different sowing dates**

| | Growth and yield parameters: Petiole length (cm) | | Middle leaflet area ($cm^2$) | | Plant height (cm) | | Yield $plot^{-1}$ (Kg) | | Yield $ha^{-1}$ (Kg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **LP** | **EP** | **LP** | **EP** | **LP** | **EP** | **LP** | **EP** | **LP** | **EP** |
| **$T_1$ (non-inoc)** | 13.46ab | 15.38e | 449ab | 757def | 45.3abc | 51.8d | 1.50c | 1.40h | 1337c | 2233h |
| **(inoc)** | 13.12abc | 19.25bc | 447ab | 796abcde | 44.4abc | 62.7abc | 2.18abc | 1.47g | 1940abc | 2345g |
| **$T_2$ (non-inoc)** | 11.58cd | 17.39d | 477ab | 744ef | 40.5c | 62.6abc | 1.47c | 1.60f | 1303c | 2551f |
| **(inoc)** | 13.40abc | 19.54abc | 522a | 826a | 47.3ab | 66.2a | 2.46ab | 1.57f | 2185ab | 2504f |
| **$T_3$ (non-inoc)** | 12.59abcd | 18.10cd | 425ab | 805abcde | 42.9bc | 64.5abc | 2.40ab | 1.73e | 2130ab | 2768e |
| **(inoc)** | 13.84a | 20.78a | 388ab | 822abcd | 49.4a | 65.9a | 2.74ab | 1.70e | 2432ab | 2716e |
| **$T_4$ (non-inoc)** | 11.22d | 17.39d | 513a | 798abcde | 42.5bc | 60.7abc | 2.21abc | 1.83d | 1965abc | 2924d |
| **(inoc)** | 14.25a | 19.47abc | 437b | 844ab | 47.8ab | 65.5ab | 2.53ab | 1.81d | 2249ab | 2897d |
| **$T_5$ (non-inoc)** | 12.87abcd | 16.97d | 450ab | 771bcde | 44.1abc | 62.6abc | 2.05bc | 1.93c | 1818bc | 3084c |
| **(inoc)** | 13.87a | 19.49abc | 528a | 799abcde | 49.5a | 65.5ab | 1.99bc | 1.89c | 1767bc | 3023c |
| **$T_6$ (non-inoc)** | 13.14abc | 17.81d | 456ab | 767cdef | 44.4abc | 61.1abc | 2.39ab | 2.19a | 2125ab | 3509a |
| **(inoc)** | 13.48ab | 19.77ab | 475ab | 836abc | 42.9bc | 65.6ab | 2.93a | 2.19a | 2604a | 3505a |
| **$T_7$ (non-inoc)** | 11.94bcd | 16.78de | 491ab | 796ab | 40.5c | 59.3c | 2.13abc | 2.07b | 1890abc | 3309b |
| **(Inoc)** | 13.62ab | 19.45abc | 456ab | 695f | 44.6abc | 60.2bc | 2.17abc | 2.04b | 1924abc | 3269b |
| **LSD (5%)** | 01.842 | 01.441 | 121.00 | 75 | 05.47 | 05.62 | 8.073 | 4.062 | 717.7 | 0065.23 |
| **MM (non-inoc)** | 12.40 | 17.12 | 465.90 | 776.74 | 42.88 | 60.38 | 2.02 | 1.82 | 1795.43 | 1911.14 |
| **MM (inoc)** | 13.65 | 19.68 | 464.70 | 806.29 | 46.49 | 64.69 | 2.43 | 1.80 | 2157.29 | 2894.14 |
| **Grand mean** | 13.026 | 18.398 | 465.296 | 791.517 | 44.682 | 62.432 | 2.224 | 1.814 | 1976.333 | 2902.714 |

**Means in a column followed by the same letter(s) do not differ significantly at 5% level of probability LP = late planting on July, 1996 and EP = early planting on June, 1997. MM = Marginal mean Non-inoc = Non-inoculated Inoc = Inoculated**

Table 3b: Effect of various levels of fertilizer without inoculum (non-inoc) and with inoculum (inoc) on yield attributes of field grown soybean [*Glycine max* L.) Merill cv.Williams-82 at two different sowing dates

| | Yield Attributes | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
| Treatments | LP | EP | LP | EP | LP | EP | LP | EP | LP | EP | LP | EP | LP | EP |
| $T_1$ (non-inoc) | 13.34e | 13.60f | 44.50c | 40.78k | 0.49c | 1.50c | 3.72b | 2.50k | 12.61a | 12.48i | 25.78ab | 23.92j | 0.99ab | 0.82k |
| (inoc) | 13.77de | 12.24h | 54.43abc | 42.55j | 3.11ab | 1.29a | 4.94ab | 2.33l | 15.05a | 8.28k | 29.78ab | 29.10f | 1.55ab | 1.53c |
| $T_2$ (non-inoc) | 14.01cde | 13.64c | 42.00c | 45.53i | 2.53bc | 0.44l | 3.72b | 3.61d | 12.27a | 12.43i | 23.17b | 27.76h | 0.99ab | 1.277g |
| (inoc) | 14.27bcde | 12.84g | 61.59abc | 46.92h | 2.94ab | 0.81g | 9.39a | 2.91i | 18.00a | 13.83e | 29.77ab | 25.79i | 1.49ab | 1.13i |
| $T_3$ (non-inoc) | 15.43ab | 12.85g | 61.50abc | 46.40h | 1.83bc | 0.61j | 7.11ab | 3.24f | 16.27a | 12.79gh | 34.72ab | 29.14f | 1.72ab | 0.59m |
| (inoc) | 14.00cde | 12.34h | 66.82ab | 48.52fg | 3.53ab | 0.85f | 7.53ab | 2.20m | 18.05a | 11.17j | 36.72ab | 33.07b | 1b.94a | 1.21h |
| $T_4$ (non-inoc) | 15.90abcd | 13.27e | 58.72abc | 47.85g | 1.33bc | 0.69i | 6.50ab | 3.73c | 17.83a | 13.61f | 31.89ab | 28.41g | 1.16ab | 1.36f |
| (inoc) | 14.57abcde | 12.86g | 58.26abc | 48.95f | 1.89bc | 0.68i | 4.16b | 3.11g | 15.39a | 15.22b | 33.49ab | 28.70fg | 1.33ab | 0.40e |
| $T_5$ (non-inoc) | 14.40bcde | 13.85b | 54.83abc | 49.82e | 1.77bc | 0.40m | 6.60ab | 3.00h | 16.55a | 14.12d | 29.05ab | 31.41d | 1.39ab | 0.89j |
| (inoc) | 14.40bcde | 13.31e | 41.82c | 51.03d | 1.83bc | 0.93e | 3.88b | 3.33e | 11.94a | 12.98g | 22.89b | 32.30c | 1.94a | 1.46d |
| $T_6$ (non-inoc) | 15.78a | 14.67a | 59.16abc | 52.20c | 2.11bc | 0.72h | 6.28ab | 4.28b | 16.50a | 18.53a | 33.00ab | 27.70h | 1.27ab | 1.76l |
| (inoc) | 15.17abc | 13.89b | 69.42a | 54.77a | 4.11a | 0.97d | 4.44ab | 2.69j | 18.00a | 14.12d | 38.11a | 35.25a | 1.77ab | 1.72b |
| $T_7$ (non-inoc) | 15.17abc | 13.51d | 55.16abc | 51.18d | 1.94bc | 0.51k | 5.11ab | 4.22a | 16.05a | 14.81c | 31.22ab | 30.01e | 0.83b | 1.12i |
| (inoc) | 14.81abcd | 13.06f | 62.44abc | 53.84b | 2.12abc | 1.22b | 5.07ab | 2.74j | 16.44a | 12.61hi | 36.50a | 35.43a | 1.72ab | 1.82a |
| LSD (5%) | 01.352 | 00.130 | 23.51 | 00.741 | 1.849 | 0.015 | 4.500 | 0.053 | 06.70NS | 0.212 | 13.18 | 00.457 | 1.090 | 0.017 |
| MM (non-inoc) | 14.74 | 13.55 | 53.63 | 47.65 | 1.71 | 0.63 | 5.50 | 3.58 | 15.44 | 14.11 | 29.83 | 28.34 | 1.20 | 0.97 |
| MM (inoc) | 14.43 | 12.93 | 59.25 | 49.51 | 2.81 | 0.90 | 5.99 | 2.76 | 16.12 | 12.60 | 32.47 | 31.38 | 1.68 | 1.47 |
| Grand mean | 14.585 | 13.243 | 56.443 | 48.582 | 2.258 | 0.799 | 5.744 | 3.110 | 15.782 | 13.355 | 31.148 | 29.856 | 1.437 | 1.220 |

Means in a column followed by the same letter(s) do not differ significantly at 5% level of probability. LP = late planting on July, 1996 and EP = early planting on June, 1997. NS = non-significant. MM = marginal mean. Non-inoc = non-inoculated. Inoc = inoculated.
(1) 100 Seed weight (g). (2) Total number of pod plant$^{-1}$. (3) Number of pod plant$^{-1}$ contained no (sterile) bean. (4) Number of pods plant$^{-1}$ contained 1 bean. (5) Number of pod plant$^{-1}$ contained 2 beans. (6) Number of pods plant$^{-1}$contained 3 beans. (7) Number of pod plant$^{-1}$ contained 4 beans.

Table 4: Correlation coefficient studies of various agronomic traits of field-grown soybean [*Glycine max* L.) Merill CV. Williams-82 in response to various level of added N fertilizer (with and without inoculum) at two different sowing dates

| Variables | | 1 LP EP | 2 LP EP | 3 LP EP | 4 LP EP | 5 LP EP | 6 LP EP | 7 LP EP | 8 LP EP | 9 LP EP | 10 LP EP | 11 LP EP | 12 LP EP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | LP | 1.000 | | | | | | | | | | | |
| | EP | 1.000 | | | | | | | | | | | |
| 2 | LP | -0.010NS | 1.000 | | | | | | | | | | |
| | EP | 0.358NS | 1.000 | | | | | | | | | | |
| 3 | LP | 0.696** | 0.108NS | 1.000 | | | | | | | | | |
| | EP | 0.738** | 0.515** | 1.000 | | | | | | | | | |
| 4 | LP | -0.079NS | -0.188NS | -0.027NS | 1.000 | | | | | | | | |
| | EP | 0.118NS | -0.054NS | 0.134NS | 1.000 | | | | | | | | |
| 5 | LP | -0.079NS | -0.188NS | -0.027NS | 0.999** | 1.000 | | | | | | | |
| | EP | 0.118NS | -0.054NS | 0.134NS | 0.998** | 1.000 | | | | | | | |
| 6 | LP | -0.325NS | -0.087NS | -0.395* | 0.496** | 0.496** | 1.000 | | | | | | |
| | EP | -0.361NS | -0.193NS | -0.121NS | 0.675** | 0.675** | 1.000 | | | | | | |
| 7 | LP | -0.306NS | -0.240NS | -0.106NS | 0.899** | 0.899** | 0.436* | 1.000 | | | | | |
| | EP | 0.326NS | -0.016NS | 0.277NS | 0.932** | 0.932** | 0.511** | 1.000 | | | | | |
| 8 | LP | -0.013NS | -0.138NS | -0.070NS | 0.595** | 0.595** | 0.129NS | 0.683** | 1.000 | | | | |
| | EP | 0.348NS | -0.096NS | -0.115NS | -0.186NS | -0.186NS | -0.437* | -0.090NS | 1.000 | | | | |
| 9 | LP | -0.191NS | -0.133NS | -0.112NS | 0.594** | 0.594** | 0.454* | 0.462** | 0.432* | 1.000 | | | |
| | EP | -0.395* | -0.072NS | -0.099NS | 0.489** | 0.489** | 0.621** | 0.311NS | -0.610** | 1.000 | | | |
| 10 | LP | -0.260NS | -0.104NS | -0.148NS | 0.838** | 0.838** | 0.453* | 0.918** | 0.520** | 0.662** | 1.000 | | |
| | EP | -0.208NS | 0.040NS | -0.014NS | 0.663** | 0.663** | 0.783** | 0.542** | -0.495** | 0.633** | 1.000 | | |
| 11 | LP | -0.197NS | -0.304NS | -0.112NS | 0.838** | 0.838** | 0.391* | 0.955** | 0.641** | 0.443* | 0.799** | 1.000 | |
| | EP | 0.501** | -0.074NS | 0.312NS | 0.699** | 0.609** | 0.035NS | 0.572** | 0.217NS | -0.195NS | -0.107NS | 1.000 | |
| 12 | LP | 0.171NS | -0.096NS | 0.191NS | 0.618** | 0.618** | 0.114NS | 0.591** | 0.454* | 0.163NS | 0.447* | 0.620** | 1.000 |
| | EP | 0.503** | -0.025NS | 0.201NS | 0.192NS | 0.193NS | -0.211NS | 0.382* | 0.528** | -0.285NS | -0.326NS | 0.605** | 1.000 |

* And ** significant at $P < 0.05$ and $P < 0.01$ respectively. While NS stands for non-significant. LP = late plantings and EP = early plantings.

their control treatment ($T_1$), but among fertilizer treatments such effects were statistically found as non-significant. Therefore the data suggested that neither various doses of fertilizer alone nor in combination with inoculum did significantly affect the soybean plant height. But sowing time did significantly and markedly affect the plant height. Some researchers (Chen, 1992; Achakzai and Kayani, 2002) reported that plant height of soybean was increased with an increase in N dose, which are in contradiction with present findings, because added N doses in particular did not play any consistent role, but are in support of results obtained by Ahmad (1972). Results also showed that by comparing the inoculated with non inoculated treatments in particular doses of fertilizer, inoculation only significantly and positively increased the plant height of $T_1$ (EP) and $T_2$ and $T_3$ (LP) treatments. On the basis of marginal mean values, inoculated treatments of both sowing dates comparatively produced taller plants (i.e., 8.42 and 6.81%) over non-inoc treatments respectively. Research revealed that application of nitrogenous fertilizer at an initial stage are essential for better plant growth of inoc soybean, but our results are in disagreement with the findings recorded by Rani and Kodandaramaiah (1997). Results further suggest that on the basis of grand mean values, the plant height of EP was noted as 39.73% greater over LP experiments. Research revealed that soybean cv.Williams-82 being a taller genotype produces taller plants when planted early. That is why EP comparatively produced taller plants over LP.

**Yield:** In response to fertilizer treatments the yield plot$^{-1}$ and yield ha$^{-1}$ was slightly ($P<0.05$) to highly ($P<0.01$) significant in both plantings, respectively (Table 2). While inoculation effect was recorded as slightly significant in LP and non-significant in EP, but reverse was true for interaction between fertilizer and inoculum.
Data regarding mean separation values (Table 3a) of yield plot$^{-1}$ and yield ha$^{-1}$ showed that fertilizer treatments generally played a significant role (except $T_2$) in LP when compared with their control ($T_1$), but within fertilizer treatments the data was statistically found non-significant. While in case of EP the fertilizer effect was noted as highly significant and $T_6$ produced maximum grain yield (i.e., 3509 kg ha$^{-1}$) followed by $T_7$ treatment (i.e., 3309 kg ha$^{-1}$). Research revealed that a supplement dose of N in

combination with P and K is very much required for the initial growth of soybean crop. However, such demands of N fertilizer as a starter dose are vary from place to place and locality to locality. In Pakistan N demand by soybean was generally recorded in the range of 20 -120 kg $ha^{-1}$. Occasionally it reached up to 140 kg N $ha^{-1}$. In present study soybean cv.Williams-82 mathematically and statistically out yielded in fertilizer dose of T6 (i.e., 100-60-30 Kg NPK $ha^{-1}$) which are in confirmation with the observations recorded by Rani and Kodandaramaiah, 1997; Akbar *et al.*, 1999; Achakzai and Kayani, 2002. Results also showed that among the same doses of fertilizer inoculation generally did not play a significant role on the yield of both planting dates and $T_6$ also mathematically produced maximum grain yield viz., 2604 and 3505 kg $ha^{-1}$ in LP and EP, respectively. Achakzai and Kayani (2002) also reported similar results. In experiments carried out through out the country, 40-50% increase in yield owe to inoculation has been found very common. Occasionally yield responses of 100 to 200% have been also recorded. As mentioned earlier that our crop of both plantings failed to produce nodules. Our findings in term of yield response by inoculation are therefore in confirmation with the achievements of few other workers (Thananusont and Vithava, 1996) and are in contradiction with the findings of most other scientists (Aslam *et al.*, 1997; Rani and Kodandaramaiah, 1997; Mitra *et al.*, 1998; Aslam *et al.*, 2000). This non-significant effect of inoculation on yield is mainly attributed to deceived nodulation. Present study have also shown that the yield $ha^{-1}$ of EP was found to be 40.87% greater over LP which signifies the importance of sowing time (months). This encouraging enhancement in grain yield could be mainly attributed to the commulative effects of fertilizer solubilization and early sowings which are strongly in support of observations recorded by Ehsanullah *et al.* (1989) and Mark *et al.* (1997).

**Yield attributes:** In response to fertilizer treatments all yield attributes were found highly significant ($P<0.01$) in EP and non-significant in LP (except 100 seed weight) (Tabel 2). The same was true for interaction between fertilizer and inoculum. While inoculation alone did also showed highly significant effect on the yield attributes of EP but non-significant on LP (except empty pods and pods contained 4 beans).

Data pertaining to mean values (Table 3b) showed that within fertilizer treatments, the 100 seed weight of EP was significantly and positively increased and heaviest grain weight was recorded in $T_6$ followed by $T_5$ dose of N fertilizer. However, in case of LP only $T_3$, $T_4$ and $T_6$ were found to be positively significant when compared with their control treatment ($T_1$). This trend of EP results is in agreement and those of LP are in disagreement with the findings of most of the researchers (Khushwaha and Chandel, 1997; Chaudhary and Jamil, 1998; Achakzai and Kayani, 2002). Results also showed that among the same doses of fertilizer, inoculum did significantly but adversely affect the 100 seed weight of EP but does not play any significant role in LP. Therefore, LP results are in conformity with Achakzai and Kayani (2002). However, on the basis of marginal mean values, the inoculation effect was calculated as 2.10 and 4.58% lesser over non-inoc experiments of LP and EP respectively. Though nodules were not formed in any set of experiment but still our findings are in confirmation with Onder and Akcin (1991) and are in contradiction with Gretzmacher *et al.* (1994). The grand mean values also showed that the 100 seed weight of LP was 10.13% heavier than that of EP. This suggests that LP just increased the seed size otherwise seed weight of EP was statistically found significant. This is substantially in agreement with most of the earlier researchers (Ehsanullah *et al.*, 1989) and in disagreement with the results obtained by Collen *et al.* (1997).

Data presented in Table 3b showed that in response to various level of added fertilizer (with and without inoculum), the total number of pods $plant^{-1}$ were significantly and positively influenced by EP and $T_6$ produced maximum number of pods $plant^{-1}$, but it remained unaffected by LP even when compared with their control treatment ($T_1$). However, on the basis of marginal mean values, LP produced 16.18% greater pods over EP which are mainly owe to different sowing times and are in accordance with the results obtained by Barik and Sahoo (1989), but are in disagreement with Ehsanullah *et al.* (1989) and Colleen *et al.* (1997).

Data pertaining to mean separation values (Table 3b) showed that number of pods $plant^{-1}$ contained various number of beans (empty and 1-4 beans) in response to different doses of fertilizer with and without inoculum were significantly enhanced in EP. Such positive effects were much pronounced on the number of pods contained no bean, 3 beans and 4 beans of inoculated experiments, but reverse was true in case of pods contained 1 and 2 beans of non-inoc treatments. Fertilizer dose of $T_6$ inoculated and non inoculated comparatively produced more pods respectively. But in case of LP neither any dose of fertilizer alone nor in combination with inoculum did generally exhibit any significant effect on the pods contained various number of beans (except sterile pods) when compared with their check ($T_1$). LP results are therefore in conformity and of EP is in contradictory with the findings reported by Lathwell and Evans (1951). Thus it can be safely concluded that N variables plus sowing time could significantly affect the relative proportion of pods particularly containing 2 and 3 beans as well as total number of pods retained by the plants. This significant enhancement could be mainly attributed to the commulative effects of early sowing and solubilization of N variables to maximize the pod set and seed set.

**Correlation studies:** The correlation coefficient (r) studies revealed that yield attributes viz., 100 seed weight, number of pods $plant^{-1}$ and number of pods contained 1, 2 and 3 beans of both sowings exhibited highly significant ($P<0.01$) and positive correlation with their respective yield (Table 4). While number of pods contained no bean and 1 bean exhibited non-consistent association with their yield. However, growth parameter viz., petiole length, middle leaflets area and plant height exhibited non-significant correlation with the yield of both planting dates. The direct effect of these yield attributes on their grain yield are strongly in support of Katiyar and Singh (1990), Zahoor and Ashiq (1992), Khan *et al.* (2000) and Achakzai and Kayani (2002).

Therefore, for the improvement of yield the information of these direct positive effects of yield attributes on yield could provide a realistic basis for a successful breeding program. These attributes can also be used a suitable selection criteria for predicting the grain yield in soybean cv.Williams-82.

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