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# Effect of Method and Time of Nitrogen Fertilizer Application on Growth, Development and Yield of Grain Sorghum

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**Abstract:** A study was established for determining the effect of nitrogen (urea) fertilizer method and time of application on the growth and yield of Sepideh and Kimia grain sorghum varieties. The experiment was conducted as a factorial-split design with four replications in Karaj (Iran) during 2003 growing season. The main plots were allocated to variety and fertilizer application methods (banding and broadcasting) and the subplots were assigned to fertilizer application time viz., at sowing and eight-leaf stages, sowing and booting stages and sowing, eight-leaf and booting stages. There was also a nitrogen fertilizer free treatment. The results of the experiment revealed that in most of the cases, responses of the sorghums varieties to broadcasting method of N fertilizer application were better than its banding. The time of N fertilizer application had different effects on similar traits of the sorghums. Variety, interactions of variety × fertilizer application method and variety×fertilizer application time showed that for most traits Kimia variety was better than Sepideh.

**Key words:** Grain sorghum, nitrogen fertilizer, fertilizer application method, fertilizer application time

## INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a crop of world-wide importance and is unique in its ability to produce under a wide array of harsh environmental conditions (House, 1995). Sorghum is an important component in traditional farming systems in the semi-arid tropics of Africa and Asia, with mean grain yields of 863 and 1175 kg ha$^{-1}$, respectively (FAO, 1999).

Nitrogen is the essential element required for plant growth in relatively large amounts. However, deficiencies of nitrogen are common. Nitrogen deficiency can result in reduced dry matter, crude protein and grain yield (Jarvis, 1996; Ashiono *et al*., 2005). Soil nutrients become depleted due to leaching of nitrogen, soil erosion and removal by crops (Zobeck *et al*., 2000).

In soils with good aeration nitrate ($NO_3^-$) is the dominant form of available nitrogen in higher plants. Its absorption and pattern of distribution in different parts of a plant is very important. Nitrate that is not absorbed by plants may contaminate underground or surface water by nitrate leaching or soil erosion. On the other hand, high absorption of nitrate causes its accumulation in plants which is one of main anxieties in recent years (Bao-ming *et al*., 2004). Increasing Nitrogen Use Efficiency (NUE) in plants is considered as a major way to decrease nitrate accumulation and its leaching in the soil. N source and method of fertilizer application have been identified as factors influencing NUE, as well as the pathway of N loss from the soil-plant system (Raun and Johnson, 1999).

There is difference for NUE, among different sorghum hybrids. Genetic variation was observed for N utilization between early and late-maturity sorghum hybrids (Kasmshita *et al*., 1998). Genotypic variation has been observed for utilization of absorbed N for biomass production and harvest index (Gardner *et al*., 1994).

The best method and time of nitrogen fertilizer application will significantly improve both quantity and quality of crops as well as NUE (Almodares, 1996).

In a study for determination of suitable time of nitrogen fertilizer application for forage sorghum in Karaj, it was concluded that, if plants are sown in proper time, three-phase distribution of nitrogen fertilizer has the best effect on total dry weight, protein and height of plants (Kohanmoo and Mazahery, 1995). Sidedress application of nitrogen fertilizer at eight-leaf growth stage is feasible and would be beneficial for sorghum (Khosla *et al*., 2000). Delaying N fertilization 40 days after sowing, rather than applying at sowing, increased dry matter and grain yield of sorghum (Joseph *et al*., 1997). Grain yield of corn was 10.5 and 11.2 Mg ha$^{-1}$ for nitrogen fertilization at planting and six-leaf stage, respectively (Sainz Rozas *et al*., 2004).

In nitrogen fertilizer banding (as starter fertilizer) of sorghum, grain yield increased by 18% (Gordon and Whitney, 1995). Plant N uptake responses indicated better utilization of subsurface knifed N than surface-broadcast

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N by wheat (Kelley and Sweeney, 2005). Although most reports show the positive effect of nitrogen fertilizer method on growth and yield of sorghum, there are still some reports about the little or no effect of nitrogen fertilizer application methods on crop yield. There was no significant effect of the method of N application in terms of dry matter yield, tillering and protein yield of sorghum-Sudangrass hybrid (Selahattin and Brohi, 2002). Compared with broadcasting, banding maintained corn grain yield in 1988 and increased it by 11% (Lehrsh *et al*., 2000). In the absence of weeds, wheat yields were similar across three N application methods including broadcast, surface pool and point injected N (Blackshaw *et al*., 2003).

As there are some contradictory reports regarding the mechanism of the effect of nitrogen fertilizer application method and timing on the growth, development and yield of sorghum, this study was conducted to determine the effect of method and time of nitrogen (urea) fertilizer application on the growth, development and yield of grain sorghum; to investigates the responses of two different grain sorghum genotypes to applied nitrogen fertilizer in regard to better nitrogen utilization efficiency.

## MATERIALS AND METHODS

This study was conducted in Karaj (Iran) in late May 2003. The experimental plots were prepared in the Research Farm of College of Agriculture, University of Tehran. The experimental design was a factorial-split arrangement within a Randomized Complete Block with four replications. The main plots were factorial combinations of variety and fertilizer application methods and the subplots were fertilizer application times. The subplots were 3×5 m and consisted of 5 rows of grain sorghum. In every replication there were four main plots and sixteen subplots.

Varieties of grain sorghum were Sepideh (Ss) and Kimia (Sk). Nitrogen (urea) fertilizer application methods were banding (Nb) and broadcasting (Ns). Fertilizer application times included fertilizer application at seed sowing and eight-leaf stages ($T_1$), sowing and booting stages ($T_2$) and sowing and eight-leaf and booting stages ($T_3$). There was a treatment with no fertilizer ($T_0$).

The field of the study was under fallow in the previous year and in the year before it was sown to barley. Sorghum was sown at a population of 166000 plant $ha^{-1}$ with row spacing of 60 cm and seeds 12 cm apart on each row. In band fertilizer application method, half of the main plot area was banded by 200 kg $ha^{-1}$ of urea fertilizer 5 cm apart from seeds and 5 cm deep in the soil. In broadcasting system urea was broadcasted by hand on the other half of the plots (except to $T_0$ plots). After application, the nitrogen fertilizer was covered with a thin layer of soil. In two partitioning phase of nitrogen fertilizer application ($T_1$ and $T_2$), one half of urea was applied each time and in three partitioning ($T_3$), one third of urea was applied. Furrow irrigation was established and weekly irrigation was performed.

Before sowing and after harvesting time of sorghum, soil samples were taken from 30 cm soil depth, using five cores for every subplot. Important physical and chemical characteristics of soil samples were determined in laboratory including soil texture, EC, pH, macronutrients (N, P, K, Ca and Mg), micronutrients (Mn, Cu, Fe and Zn), $CaCO_3$, $CO_3$, $Cl^-$ and Mo.

From sowing to harvesting time emerging time, flowering time, plant height, leaf dry weight, leaf area, specific leaf area, total dry weight and grain yield were measured.

SPSS and SAS programs were used for analysis of variance, Duncan's Multiple Range Test and correlations of traits.

## RESULTS AND DISCUSSION

Nitrogen Fertilizer application Method (NFM) had a significant effect on Specific Leaf Area (SLA), Total Dry Weight (TDW) and Grain Yield (GY). For the mentioned traits Ns had a better effect than Nb (Table 1).

There are different reports about relation between SLA and leaf nitrogen content. In a study on ten annual and nine perennial grass species, the correlation between specific leaf area and leaf nitrogen content expressed on a dry matter basis was negative in annuals and positive in perennials (Garnier *et al*., 1997).

The organic N content per unit leaf area was lower for the high-SLA species of ten dicotyledonous species that differed inherently in SLA (Poorter and Evans, 1998).

Soil factors including pH, EC, soil temperature, macro and micro nutrients as well as irrigation methods all can be affected by NFM. Best solubility and availability of $NO_3^-$ for many plants is in pH = 6.5-7.5. Soil pH of the experimental site was more than 8 and it could possibly caused decreasing of N fertilizer solubility and availability, so urea had less effect on some sorghum traits.

Banding N one side of a row, rather than broadcasting, maintained or increased grain yield, increased silage yield up to 26% (Lehrsh *et al*., 2000). Final wheat grain yield and grain N content were not affected by N placement in plowed plots (Rao and Dao, 1996).

Variety effect was significant for emerging time, plant height, Leaf Dry Weight (LDW), Leaf Area (LA) and TDW. Emerging time for Ss was more than Sk, may be

Table 1: Means comparison of main effects of treatments on vegetative and generative traits of grain sorghum*

| Treatments | Emerging time (day) | Flowering time (day) | Plant height (cm) | LDW (g cm$^{-2}$) | LA (cm$^2$·m$^{-2}$) | SLA (m$^2$·g$^{-1}$) | TDW (kg ha$^{-1}$) | GY (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Nb | 12.9a | 82.1a | 105.3a | 324.9a | 44552a | 0.0115b | 4367.2b | 2115.2b |
| Ns | 13.5a | 82.5a | 105.5a | 323.3a | 45921a | 0.0134a | 5271.3a | 3049.9a |
| Sk | 11.0b | 82.3a | 101.3b | 347.6a | 48273a | 0.0128a | 5359.3a | 2710.3a |
| Ss | 15.4a | 82.2a | 109.6a | 300.6b | 42200b | 0.0121a | 4279.2b | 2454.8a |
| $T_0$ | 14.7a | 79.7c | 101.2b | 247.8c | 38429c | 0.0156a | 4252.0b | 1983.8b |
| $T_1$ | 13.1b | 84.1a | 105.9a | 326.2b | 44254b | 0.0112b | 5537.8a | 2611.0a |
| $T_2$ | 12.9b | 82.7b | 105.4a | 354.6a | 45601b | 0.0112b | 4422.4b | 3006.5a |
| $T_3$ | 12.1c | 82.6b | 104.8a | 367.7a | 52662a | 0.0118b | 5064.8a | 2728.9a |

*DMRT= Duncan's Multiple Range Test, Means with the same letter(s) have no significant difference at 5% level probability

Table 2: Means comparison of different vegetative and generative traits of grain sorghum varieties at different methods of N fertilizer application*

| Treatments | Emerging time (day) | Flowering time (day) | Plant height (cm) | LDW (g cm$^{-2}$) | LA (cm$^2$ m$^{-2}$) | SLA (m$^2$ g$^{-1}$) | TDW (kg ha$^{-1}$) | GY (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| SkNb | 10.6b | 82.3ab | 101.3b | 358.3a | 49533a | 0.010a | 4550.3a | 1924.7b |
| SsNb | 15.3a | 81.9b | 109.4a | 291.5b | 39572c | 0.010a | 4184a | 2305.8ab |
| SkNs | 11.4b | 82.4ab | 101.2b | 336.8a | 47013ab | 0.010a | 4447.7a | 3495.9a |
| SsNs | 15.6a | 82.6a | 109.9a | 309.7b | 44828b | 0.010a | 4374.3a | 2603.8ab |

*DMRT= Duncan's Multiple Range Test, Means with the same letter(s) have no significant difference at 5% level probability

Table 3: Coefficients of correlation between the traits of grain sorghum

| | Emerging time | Flowering time | Leaf area | Leaf dry weight | Specific leaf area | Total dry weight | Plant height | Grain yield |
|---|---|---|---|---|---|---|---|---|
| Emerging time | 1 | 0.505* | 0.783** | 0.561* | 0.708** | 0.290* | 0.123 | 0.188 |
| Flowering time | | 1 | 0.547* | 0.692** | 0.775** | 0.670** | 0.717** | 0.444* |
| Leaf area | | | 1 | 0.508** | 0.628** | 0.424* | -0.174 | 0.180 |
| Leaf dry weight | | | | 1 | 0.835** | 0.661* | -0.561* | 0.046 |
| Specific leaf area | | | | | 1 | 0.286 | -0.593* | 0.010 |
| Total dry weight | | | | | | 1 | 0.402* | 0.611* |
| Plant height | | | | | | | 1 | 0.041 |
| Grain yield | | | | | | | | 1 |

*: Significant at 5% level probability, **: Significant at 1% level probability

Table 4: Means comparison of different vegetative and generative traits of grain sorghum at different times and methods of N fertilizer application*

| Treatment | Emerging time (day) | Flowering time (day) | Plant height (cm) | LDW (g cm$^{-2}$) | LA (cm$^2$·m$^{-2}$) | SLA (m$^2$ g$^{-1}$) | TDW (kg ha$^{-1}$) | GY (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| $NbT_1$ | 14.8a | 80d | 107.5ab | 256.5c | 40149de | 0.018ab | 4221.7a | 2390.6bc |
| $NbT_2$ | 12.5de | 83.9ab | 105.8ab | 344.9a | 47501bc | 0.010d | 4709.4a | 2256.1bc |
| $NbT_3$ | 13.8bc | 84.3a | 106ab | 307.6b | 41007de | 0.013cd | 4421a | 2965.1ab |
| $NsT_1$ | 13.3cd | 82.9bc | 102.3b | 357.2a | 47102bc | 0.010d | 4559.3a | 3353.2a |
| $NsT_2$ | 14e | 82.5c | 103.2ab | 363.6a | 49899b | 0.010d | 4191.5a | 2104.6cd |
| $NsT_3$ | 12.1e | 82.8bc | 106.5ab | 371.9a | 55425a | 0.015bc | 4442.1a | 3489.8a |

*DMRT= Duncan's Multiple Range Test, Means with the same letter(s) have no significant difference at 5% level probability

Table 5: Means comparison of different vegetative and generative traits of grain sorghum varieties at different times of N fertilizer application*

| Treatments | Emerging time (day) | Flowering time (day) | Plant height (cm) | LDW (g cm$^{-2}$) | LA (cm$^2$·m$^{-2}$) | SLA (m$^2$ g$^{-1}$) | TDW (kg ha$^{-1}$) | Gy (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| $S_kT_1$ | 11.1d | 84.5a | 101.2b | 310.3cd | 40874de | 0.010d | 4921.4a | 2949.7ab |
| $S_kT_2$ | 10.8d | 82.1c | 101.3b | 390.2a | 53550a | 0.010d | 4249.1ab | 3057.1a |
| $S_kT3$ | 9.5e | 82.7bc | 101.9b | 404.0a | 54492a | 0.010d | 4732.1ab | 2853.3ab |
| $S_sT_1$ | 15.1b | 83.6ab | 109.5a | 342.1b | 47634bc | 0.012cd | 4410.5ab | 2272.2bc |
| $S_sT_2$ | 15.1b | 83.3bc | 109.4a | 319.0bc | 37653e | 0.010d | 4595.7ab | 2956ab |
| $S_sT_3$ | 14.6b | 82.5bc | 107.7a | 331.4bc | 50832ab | 0.015bc | 3901.5b | 2604.6abc |

*DMRT= Duncan's Multiple Range Test, means with the same letter (s) have no significant difference at 5% level probability

because of smaller seed size of Ss in compared to Sk. For LDW, LA and TDW, Sk had a better performance than Ss, but for plant height, Ss was superior (Table 1). This could be better explained by genetically differences rather than environmental factors (Ss is genetically a taller sorghum than Sk). Interaction of variety by NFM was significant for emerging time, flowering time, plant height, LDW, LA and GY (Table 2).

The most and the least emerging time was for NbSk and NsSs, respectively. Ns in comparison with Nb caused later flowering of Ss. The least and the most LA and LDW were observed in Nb for Ss and Sk, respectively. It was known that the sorghum varieties had reverse response to NFM. There was a significant difference for the effect of Ns on LDW of each variety. Ns had a better effect on GY of Sk in comparison with Nb (Table 2). From these

comparisons it is concluded that in broadcasting method, Sk is more efficient in nitrogen utilization of urea for seed production.

Nitrogen Fertilizer application Time (NFT), had significant effect on emerging time, days to flowering, LDW, LA and TDW (Table 1). In plots with no N fertilizer ($T_0$), longer emerging time was observed. Considering positive effect of nitrogen on seed germination, this could be expected. Flowering time had a positive correlation of 0.547*, 0.692** and 0.670** with LA, LDW and TDW, respectively (Table 3).These correlations show the importance of flowering time and its role in sorghum grain yield.

GY in $T_2$ was more than the other treatments but it had not significant difference with other times except $T_0$ treatment (Table 1). A positive correlation of 0.611* was observed between GY and TDW (Table 3). If favorable environmental conditions at seed formation period exist, more vegetative organs of a plant can be a positive factor in increasing of grain yield.

Interaction of NFM*NFT was significant at 5% level for emerging time, flowering time, LDW, LA and GY. Flowering time of $NbT_1$ was shorter than $NsT_1$, but $NbT_2$ and $NbT_3$ treatments in comparison with $NsT_2$ and $NsT_3$ postponed flowering time (Table 4).

In similar fertilizer application times, in broadcasting method of N fertilizer there was more increase in LDW and LA compared to banding system. SLA was significantly more in $NbT_1$ treatment compared to $NsT_1$. In both NFM, the least and the most GY was in $T_2$ and $T_3$, respectively. $NsT_1$ and $NsT_3$ produced better GY than $NbT_1$ and $NbT_3$ and on the other hand, GY was more in $NbT_2$ than $NsT_2$ (Table 4).

Interaction of variety*NFT was significant for emerging time, flowering time, plant height, LDW, LA, SLA and TDW. The shortest and the longest emerging time were observed in $SkT_3$, $SsT_1$ and $SsT_2$, respectively. $SkT_1$ and $SsT_1$ had the longest flowering time. The least and the most plant heights were observed in $SkT_1$ and $SsT_1$ treatments (Table 5).

These results indicate that the response of Sepideh and Kimia sorghum varieties to NFT is adverse for their height. $SkT_3$ treatment produced the most LA and LDW. The most LA for both varieties was produced in $T_3$; however, the most LDW for Ss was obtained in $T_1$. The least LDW and LA were in $SkT_1$ and $SsT_2$, respectively. A significant difference was observed for SLA between $SsT_2$ and $SsT_3$ (Table 5). Correlation between SLA with LDW and LA was 0.835** and 0.628*, respectively (Table 3).

Different NFT had different significant effect on TDW of every variety. The most and the least amount of TDW was in $SkT_1$ and $SsT_3$, respectively (Table 5). Regarding the high importance of TDW in sorghum and its relation to grain yield, enough attention should be paid to the time of nitrogen fertilizer application. Concluding from the results of this experiment, it is known that in most cases the response of the sorghum varieties to broadcasting of urea fertilizer was better than its banding. The sorghum varieties had different responses to NFT for similar traits. Interactions of variety* NFM and variety* NFT indicate that for most traits Kimia sorghum variety was better than Sepideh.

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