Selection of fertilization method and fertilizer application rate on corn yield

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Abstract: A field experiment was carried out on the silty clay soil of Lack-Lack agricultural research field during two years to select the most suitable fertilization method (fertilizer broadcasting, fertilizer pouring in the furrow, fertilizer banding placement in one side and both sides of seedling) and application rate (30, 60 and 90 kg of net nitrogen from source of urea fertilizer/ha) on corn yield and yield components in Hamedan province in Iran. Corn yield components evaluated were plant height, corn height, percentage of corncob, thousand-kernel mass and net yield. A factorial experiment with 12 treatments (four methods × three levels) was replicated three times in 36 test plots. By analysis of variance and comparison of treatment means using DMRT (Duncan's new Multiple Range Test), application methods had no significant effect on plant height, corn height and percentage of corncob, but net yield and thousand-kernel mass were highly influenced. In addition, effect of fertilizer application rate on plant height, corn height, and percentage of corncob was not significant but was highly significant on net yield and thousand-kernel mass. Interactional effects of method × level on plant height, corn height, percentage of corncob and thousand-kernel mass were not significant but their effects on net yield were very significant. In this study, fertilizer banding on one side of seedling with 60 kg of nitrogen/ha applied 10 cm from the seedling at 5 cm soil depth was selected as the most suitable treatment.

Keywords: fertilization methods, nitrogen, fertilizer application rates, corn, placement fertilizer, Iran

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1 Introduction

Corn (*Zea mays* L.) is extensively cultivated more than other crops as a nutrient food for human and favorable forage for animals all over the world. Bio-energy industries strongly believe that corn is a powerful energy source for living beings (Xu et al., 2004). Corn is the third most strategic cereal crop throughout the world after rice and wheat, and has been recognized as a premier cereal crop (Muthukumar et al., 2005).

In Iran, corn as a main grain forage crop has an average yield of more than 8 ton/ha, and the yield increases year-by-year (Shakarami and Rafiee, 2009).

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Increasing population and fear of food shortage in Iran has caused Iran's Ministry of Agriculture to enhance the corn production (arable land and yield) (Yazdani et al., 2008). Nitrogen as a nutritious substance has a main role in affecting corn yield. Precise N fertilizer rate for corn is extremely important to increase the yield and profit and reduce environmental affects (Al-Bakeir, 2003; Ruffo et al., 2006).

Some effective factors on corn yield and production costs are climatic and soil conditions, variety, fertilizer application rate, and fertilization method. Selecting the suitable mechanization method could increase the crop production. Therefore, selecting the best fertilization method is very important in cornfield to increase corn yield. In conventional fertilization method with centrifugal fertilization machine or manual broadcasting method (topdressing), some problems observed are losing the great part of fertilizer due to rain or irrigation, sublimation by sun radiation, a little leaf burn, and growth of weeds (Fertilizer can be applied on the surface across an entire field through broadcast applications. When the fertilizer is spread across the soil surface before cultivator, it's called a "broadcast or topdress" application).

Disparate topdressing will result in nonuniform growth, wasting of fertilizer, and decreasing the usage coefficient of plant (Kasraei, 1993; Malakoti, 1999). Banding fertilization (applied fertilizer affecting root region of seedling) reduces the production costs. This method allows applying fertilizer and weed killer, concurrently. Sosnoaya (1972) applied fertilizer and weed killer, simultaneously resulted in increasing corn yield.

Gorbacheva et al. (1986) in Russia carried out research on forage corn, autumn wheat, and sunflower. It was observed that 5-15 cm is the best depth to place the fertilizer. Vriyo et al. (1977) evaluated different fertilization methods and their effects on corn yield. Their results indicated that regional fertilization has more efficiency than surface fertilizer topdressing.

Hornung (1992) in Germany conducted another research with banding chemical fertilizer at 5 cm beside and below the seed. The result showed primary growing acceleration affects the proper place of fertilizer. Results of some studies showed that N-fertilizer banding increased fertilizer absorption by the plant (Bandel et al., 1984; Fox et al., 1986; Howard and Tyler, 1989; Mengel et al., 1982; Tomar and Soper, 1981; Touchton and Hargrove, 1982). As the costs in this method (Labor, equipment, implements, and energy costs) are much more than custom methods, farmers select the manual fertilization method and use extra N-fertilizer rates for preventing the efficiency reduction of N absorption.

Randall (1984) expressed that the new fertilization techniques can enhance the nitrogen usage efficiency and economical efficiency. It can be helpful on environmental pollution control, as well.

A first-rate N-fertilizer application policy according to best management practice will be achieved by considering soil and plant condition during the growing period (Olfs et al., 2005).

The fieldwork was initiated in May of 2006, and the data were collected during a two-year period. Our research objectives were determination of the best fertilization method and N-fertilizer application rate on corn yield and yield components.

2 Material and methods

2.1 Site description

The study was carried out on Lack-Lack agricultural research field located 47 km west of Hamedan, Iran. This site is located at 34°40′N latitude and 47°56′E longitude, Asadabad city, Hamedan, Iran. The average height of the site is 1585 m above sea level. The climate is cold and semi-arid with air temperature of –2°C to 37°C and average rainfall of 330 mm/year. The area was about 8190 m^2 (63 m × 130 m). Plots with an area of 135 m^2 (4.5 m × 30 m) were essentially weed free during the study period. Each treatment covered six rows with 75 cm row spacing and 20.5 cm of seedlings distance apart on ridge. Single cross 704 variety (late-maturity (SC704)) with compression of 65,000 seedlings per hectare was applied.

2.2 Soil sampling and analysis

Soil routine analysis was conducted before planting. Ten samples were collected from whole field at 30 cm depth. After analyzing, soil type was classified as silty clay.

2.3 Statistical analysis

A factorial experiment with 12 treatments (four methods × three rates) was replicated three times in 36 test plots. Analysis of variance (ANOVA) was conducted using MSTAT-C program (MSTAT-C is a computer based Statistical software packages) and comparison of treatment means using DMRT (Duncan's new Multiple Range Test).

2.4 Fertilizer application method

Our research utilized the whole rate of phosphor fertilizer and half rate of N-fertilizer in the sowing phase based on research results of Azari (1994), while planting method and fertilization method for all treatments were constant. Another half rate of N-fertilizer was used as different treatments when seven to nine leaves were observed. Weed control and fertilization were done, concurrently.

Four fertilizing methods include fertilizer broadcasting (FB), fertilizer pouring in the furrow (FPF), fertilizer banding placement in one side of seedling (FBPOSS), and fertilizer banding placement in both sides of seedling (FBPBSS), and three N-fertilizer rates (30, 60 and 90 kg of N from source of urea (46% N) fertilizer/ha) with three replications.

Fertilizer broadcasting (fertilizer broadcasting (FB)) was done manually, while fertilizer placement was accomplished by innovative integrated machine designed by Agricultural and Natural Resource Research Center of Hamedan (ANRRCH) (Figure 1). This machine consists of fertilizer unit (hopper, distributers, delivery or falling tubes and fertilizer openers), herbicide sprayer (tank, tubes, pump, pressure regulator and indicator, nozzle, boom and coupling), cultivator (knives and furrowers), power transmission system, and frame. This machine was able to place N-fertilizer using three applied methods: fertilizer pouring in the furrow (FPF), fertilizer banding placement in one side of seedling (FBPOSS), and fertilizer banding placement in both sides of seedling (FBPBSS)).

2.5 Corn yield components quantifying

For yield components determination, two 10 m rows were selected from each plot, randomly. After measuring plant height and corn height, all corns in these two rows from all plots were harvested. Subsequently, percentage of corncob, thousand-kernel mass, and net yield were quantified.

1. Square-turn knife 2. Three point hitch 3. Toolbar 4. Delivery tube 5. Distributor 6. Fertilizer hopper 7. Herbicide tank 8. Fertilizer Opener

Figure 1 Innovative and integrated machine designed by ANRRCH

3 Results and discussion

3.1 Effects of fertilization methods

Analysis of variance on results for two year performance of this project indicated that the effects of fertilization methods on plant height, corn height, and percentage of corncob at 5% probability level was not significant. However, the effect of fertilization method on thousand-kernel mass and net yield at 1% and 5% probability level was significant, respectively (Table 1).

Table 1 Analysis of variance of corn yield components at different levels of fertilization method and fertilizer application rate

Difference resources	F values				
	Plant height	Corn height	Percentage of corncob	Net yield	Thousand kernel mass
Replication	5.6501^{ns}	1.9072^{ns}	8.8216**	16.7829**	45.4293**
Fertilization method	0.2340^{ns}	0.3469^{ns}	1.1593^{ns}	26.1130**	3.6160*
Fertilizer application rate	0.4985^{ns}	0.5848^{ns}	2.4712^{ns}	24.6670**	5.2985**
Method × Application rate	2.0559^{ns}	0.9057^{ns}	0.9472^{ns}	2.5647*	2.2260^{ns}

Note: ns: Not significant; *: Significant at 5% level; **: Significant at 1% level.

Table 2 shows that, FBPBSS method produced the highest thousand-kernel mass followed by FBPOSS. Comparing the means in Table 2, both sides treatment had the highest net yield, followed by one side treatment. In addition, FBPOSS is the most suitable method from point of view of economic aspect, because FBPOSS replaces fertilizer in one side of seedlings, while FBPBSS replaces it in both sides of seedling, then FBPOSS needs fewer components than FBPBSS, such as distributor, delivery tube, and fertilizer opener. This method improves the net yield, and similar to the results of other researchers (Vriyo et al., 1977).

Table 2 Comparing corn yield components means at different levels of fertilization method

Fertilization Method	Means of Crop Parameters				
	Plant height /cm	Corn height /cm	Percentage of corncob /%	Net yield /ton ha^{-1}	Thousand kernel mass /gr
Fertilization Broadcasting (FB)	192.9^{a}	107.1^{a}	12.7^{a}	6.5^{b}	268.6^{ab}
Fertilization Pouring in the Furrow (FPF)	191.8^{a}	107.1^{a}	12.4^{a}	7.0^{b}	259.6^{a}
Fertilization Banding Placement in One Side of Seedling (FBPOSS)	192.5^{a}	105.6^{a}	12.7^{a}	8.6^{a}	277.3^{ab}
Fertilization Banding Placement in Both Sides of Seedling (FBPBSS)	190.9^{a}	106.0^{a}	12.3^{a}	9.5^{a}	280.7^{a}

Note: Means in every column with similar capital letters are not significantly different at 1% level by DMRT.

3.2 Effects of fertilizer application rates

Combined analysis of variance results during two years (Table 1) showed that the effect of fertilizer application rate on plant height, corn height, and percentage of corncob was not significant, but on thousand kernel mass and net yield was significant (at 1% level). Table 3 shows that 90 kg N-fertilizer/ha increased thousand-kernel mass slightly higher than using 60 kg N-fertilizer/ha.

Table 3 Comparing corn yield components means at different levels of fertilizer application rate

Net N-fertilizer values /kg ha^{-1}	Plant height /cm	Corn height /cm	Percentage of corncob /%	Net yield /ton ha^{-1}	Thousand kernel mass /gr
30	192.3^{a}	105.8^{a}	12.8^{a}	6.6^{b}	263.9^{b}
60	190.8^{a}	106.1^{a}	12.3^{a}	8.1^{a}	268.0^{ab}
90	193.0^{a}	107.4^{a}	12.6^{a}	8.9^{a}	282.8^{a}

Note: Means in every column with similar capital letters are not significantly different at 1% level by DMRT.

From economic and environmental health point of view, using 60 Kg N-fertilizer/ha is more suitable than 90 kg N-fertilizer/ha. With reduction of N-fertilizer by 33.3%, the field costs will be reduced (Randall, 1984).

3.3 Interactional effects of fertilization methods and fertilizer application rates

Table 1 illustrates that interactional effect of fertilization method and fertilizer application rate on plant height, corn height, percentage of corncob and thousand-kernel mass was not significant, but was significant on net yield at 5% probability level. Table 4 shows that the net yield (ton/ha) using FBPOSS and FBPBSS methods with the values of 60 and 90 kg N-fertilizer/ha, are at the same level and show no significant difference. Although, the net yield in FBPBSS method is the highest (10.920 ton/ha), and is lower (9.463 ton/ha) for FBPOSS method, FBPOSS method is more economical than FBPBSS method because of lower number of distributors, delivery tubes, openers and other components (Fox et al., 1986).

Table 4 Comparing interactional fertilization method means and its values on net yield (ton/ha)

Fertilization method	Net N-fertilizer application rates/kg ha^{-1}		
	30	60	90
Fertilization Broadcasting (FB)	6.2^{de}	5.8^{e}	7.3^{de}
Fertilization Pouring in the Furrow (FPF)	5.8^{e}	7.6^{cde}	7.7^{cde}
Fertilization Banding Placement in One Side of Seedling (FBPOSS)	6.6^{de}	9.5^{abc}	9.7^{b}
Fertilization Banding Placement in Both Sides of Seedling (FBPBSS)	7.9^{bcd}	9.5^{abc}	10.9^{a}

Accordingly, FBPOSS method by 60 kg N-fertilizer/ha is recommended. On the other hand, net yield in FB method (90 kg N-fertilizer/ha) is 7.321 ton/ha, while FBPOSS with the lowest amount of fertilizer has the highest net value on corn (Figure 2).

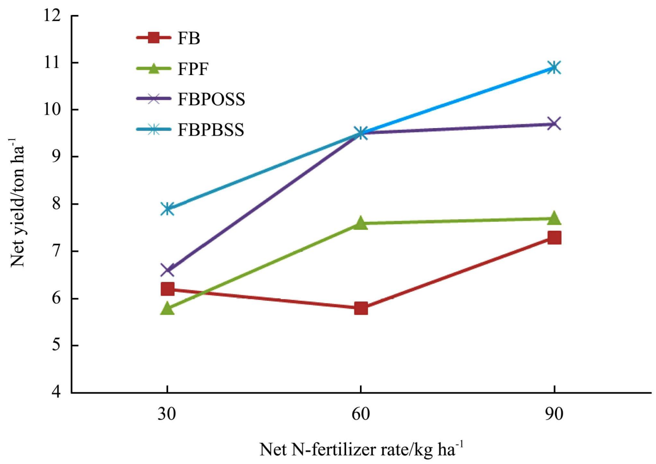

Figure 2 The relation between net yield and net N-fertilizer application rate for different fertilization methods

4 Conclusions

Analysis of variance on results for two year performance of this project indicated that the effects of fertilization methods and fertilizer application rate on thousand-kernel mass and net yield were significant. However, the effect of interactional fertilization method and fertilizer application rate was significant on net yield at 5% probability level. Accordingly, Fertilizer banding placement in one side of seedling (FBPOSS), with 10 cm space beside the seedling at 5 cm soil depth and with 60 kg of nitrogen fertilizer/ha in source of urea fertilizer was recognized as the most suitable treatment for fertilization operation of corn in Hamedan.

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