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# Influence of moisture conservation and integrated nutrient management on growth and productivity of summer maize in southern Afghanistan

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## Abstract

A field experiments was conducted during summer season of 2017 to determine the effect of moisture conservation and (INM) on growth and productivity of maize at Tarnak Farm of Afghanistan National Agriculture Sciences and Technology University (ANASTU), Kandahar province of Afghanistan. The experiment comprised of 12 treatment combinations *viz.*, 3-moisture conservation practices (MCP) including flat bed (FB), raised bed (RB) and raised bed + mulch @ 3 t ha$^{-1}$ (RBM) in main-plots and 4-INM options, control (no-nutrient application), 100% recommended dose of fertilizers (RDF, 150:6040 NPK), 50% RDF + FYM (5 t ha-1) + 2 foliar sprays of urea (2%) and 50% RDF + FYM (10 t ha$^{-1}$) + 2 foliar sprays of urea (2%) in sub-plots. The treatments were set in a three-time replicated split-plot design. Results revealed that RBM recorded the highest values of growth and yield attributes, which consequently led to the highest grain and straw yields. Raised bed and RBM showed similar effect on growth, yield attributes and productivity of maize. Grain yield (5.22 t ha$^{-1}$) with RBM was 14.5% higher over FB (4.56 t ha-1) whereas, RB without mulch produced 6.1% higher grain yield (4.84 t ha$^{-1}$) over FB planting. The higher growth and productivity of maize with RBM was likely due to increased availability of moisture for a longer duration which might also have enhanced the nutrient utilization during dry and hot summer season. Among the INM options, 50% RDF + FYM (10 t ha$^{-1}$) + 2 foliar sprays of urea (2%) recorded the maximum values for growth, yield traits and grain yield (5.69 t ha-1). This INM option was at par with 100% RDF (5.44 t/ha) and significantly better than 50% RDF + FYM (5 t/ha) + 2 foliar sprays of urea (2%) (5.06 t ha$^{-1}$) and control (3.31 t ha$^{-1}$). Thus, RBM and 50% RDF + FYM (10 t ha$^{-1}$) + 2 foliar sprays of urea (2%) were the most suitable MCP and INM option to obtain highest productivity of maize in Southern region of Afganistan.

**Key words**: Flat bed, integrated nutrient management, maize, mulch, productivity and raised bed.

Maize (*Zea mays* L.) is one of the most important food and feed cereals in the world to meet growing challenges like ever increasing demand of food-grains, fodder and fuel. This crop is one of the most versatile emerging crops having wider adaptability under varied agro-climatic and edaphic conditions ranging from 600N to 400S latitude, from below sea-level to an altitude of > 4,000 m with rainfall varying from < 25 cm to > 1,000 cm (Sharma and Dass, 2012; Ghosh *et al.*, 2017; Kumari *et al.*, 2017). Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 183 million ha (m ha) in about 160 countries, producing 1022 million tons

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(mt) grain with an average yield of 5.57 t $ha^{-1}$ that contributes about 40% in the global cereal grain production. Maize grain is used as human food, animal feed and also used as raw material in textile, pharmaceutical, cosmetic industries, high quality corn oil, protein, alcoholic beverages, food sweeteners, *etc.* (Dass *et al.*, 2015).

In Afghanistan, maize is one of the most important food cereals and it is grown throughout the country. It ranks third after wheat and rice in term of total production. In Afghanistan, the bulk of maize produced is used for livestock feeding and also as human food (directly or after processing of the grain). The total production of maize in 2014-15 was 0.316 mt and total area was 0.127 mha. In comparison with 2013-2014 the production increased by 1.3% and area decreased by 10.5%. The average productivity of maize is 2.48 t $ha^{-1}$ (Anonymous, 2015), which is half of the world's average yield of 5.5 t $ha^{-1}$ (FAOSTAT, 2015). Presently, the main limitations to maize-wheat production for small-scale farmers in Afghanistan include lack of improved varieties, poor availability of good quality seed, lack of high quality fertilizers, inadequate production technologies and irrigation, road and market infrastructures (Jilani *et al.*, 2013). Low productivity of maize is attributed to many factors like frequent occurrence of drought, declining of soil fertility, poor agronomic practice, limited use of input, and lack of credit facilities, poor seed quality, disease, insect, pests and weeds particularly CIMMYT (2004).

There is stagnation in crop yield, particularly in intensive cropping regions due to imbalanced use of fertilizers and continuous growing of crops (exhaustive) rendering in several nutrients deficient. Moreover, supplying plant nutrients through chemical fertilizers only is constrained by issues like involvement of high costs, deficiency of nutrients other than applied ones, and environmental pollution, and thus cannot be relied upon for a long-time. On the other hand, the organic manures though contain all nutrients, but their concentration is very low and, thus, cannot meet the crop requirements. Thus applying prescribed quantity of plant nutrients through organics only is practically infeasible as a large quantity of organics is required which may not be available. Thus too produce more with better quality of product and at the same time sustain soil health, a combined application of organics and chemical fertilizers is important. Highest productivity of crops in sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying appropriate combination of different organic manures and inorganic fertilizers (Dass *et al.*, 2008; Dass *et al.*, 2013). In this context, optimizing organic and inorganic manure (INM) for maize is important for higher productivity, profitability and resource-use efficiency.

Apart from plant nutrients, adequate availability of moisture in the soil is essential for better growth and productivity of crops because soil moisture regimes influence the availability and uptake of nutrients besides improving soil conditions and mediating many physiological processing in the plant system (Dass and Bhattacharyya, 2017). Mulches improve the crop productivity during the high evapo-transpiration period by conserving the soil moisture and reduce temperature because of decreased soil disturbance and increased residue accumulation at the soil surface (Chaudhary *et al.*, 2003; Dass *et al.*, 2006; Zhang *et al.*, 2009; Dass and Bhatacharya, 2017).

Growing scarcity of water invokes to rethink and rationalize water supply to maize crop in such a way that improves nutrient uptake, yield and water productivity of this crop. The Kandahar region of Afghanistan is a dry region and faces scarcity of water for domestic use and irrigation purpose. Under restricted availability of irrigation water, *in-situ* conservation and management of rainwater can reduce the water stress in maize. Moisture conservation practices like RB planting and use of crop residues as mulch have been found to improve productivity of maize and could be considered as potential moisture conservation methods for improving maize growth and productivity. Response of maize to nutrient management in general and INM in particular may differ under different moisture conservation methods. However, no scientific research on responses of maize to moisture conservation methods and INM has been reported from Afghanistan. Hence, the objective of the present investigation was to assess the growth and yield of maize under various moisture conservation and INM options in southern Afganistan.

## Materials and Methods

The field experiments was carried out during summer season of 2017 to study the effect of moisture conservation and integrated nutrient management on growth and productivity of maize at Tarnak Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar province of Afghanistan located between latitude 31° 30' 26" N and longitude 65° 51' 1" E with an elevation of 986 m above the mean sea level. Soil of the experimental plot was clay loam consisting of 44% sand, 11.5% silt and 45% clay with pH of 7.8 which was moderately alkaline in nature. Soil was low in organic C (0.49%), available N (39.18 mg/kg), P (19.98 mg/kg) and K (148.0 mg/kg) which was suitable for maize cultivation. The average daily temperature ranges around of 30 and 48°C during maize growing season (summer season). The average annual rainfall is 191 mm in the Kandahar region of Afghanistan but no rainfall was received during crop growth period.

The field experiment was conducted in a split-plot design with 12-treatment combinations consisting of different type of planting methods with mulch as moisture conservation practice and combination of recommended doses of (NPK) fertilizers (RDF) and FYM as INM with 3-replications. Three moisture conservation practices, flat bed (FB), raised bed (RB) and raised bed + mulching(RBM) were allotted in main-plots and 4-INM options, control (no-nutrient application), 100% recommended dose of fertilizers (RDF, 150:6040 NPK), 50% RDF + FYM (5 t $ha^{-1}$) + 2 foliar sprays of urea (2%) and 50% RDF + FYM (10 t $ha^{-1}$) + 2 foliar sprays of urea (2%) in sub-plots. The maize hybrid "Shemal 08" was used for this study. The field was ploughed thoroughly using the mould-board ploughing, exposing soil to the sun light for three days, and subsequently prepared thoroughly by tilling twice with a cultivator. The levelling of experimental units (plots) was done manually and weeds, stubbles and crop residues were collected and removed from the experi-mental field to get well pulverized soil. Seeds were sown on May 1, 2017 in rows at a plating spacing of 60 × 20 cm. FYM, N, P, K and urea sprays were applied according to treatments. The entire dose of FYM, P, K and half of N were applied at the time of sowing and the remaining amount of N was applied 25 days after sowing (DAS) of maize. Urea, triple super phosphate (TSP) and muriate of potash (MOP) were used as a source of NPK, respectively. Foliar spray of 2% urea was done each at knee-high and tasseling stage. The number of irrigations was 10 for mulch and 12 for without mulch plots. The other agronomic practices and plant protection measures were kept normal and uniform to all the treatments. The data on plant characters, yield components and yield were acquisitioned using the standard procedures (Rana *et al.* 2014). All data were analysed statistically using the F-test as per the standard procedure. CD values at P = 0.05 were used to determine the significance of differences among treatment means.

## Results and Discussion

### Growth parameters

The plant height, leaf area and dry matter accumulation of maize were significantly affected by the MCP and INM options (Table 1). Raised bed + mulch (3 t/ha) recorded the maximum plant height, leaf area and dry matter accumu-lation at all growth stages. Raised bed + mulch (3 t/ha) enhanced average height of plants significantly over FB planting at knee-high and maturity stages. Plant height in RBM was statistically at par with RB; however, plant height in FB was on par with RB at all growth stages. The maximum leaf area per plant at knee-high and tasseling stages, was recorded with RBM (2578 and 5700 $cm^2$, respectively), which was significantly greater as compared to RB (2371 and 5308 $cm^2$) and FB (2185 and 5144 $cm^2$) at tasseling stage and significantly higher than FB only at knee-high stage. Raised bed + mulch increased significantly the dry matter production over RB and FB at tasseling stage. However; at other growth stages, RBM and RB were alike. Flatbed

**Table 1. Effect of moisture conservation and integrated nutrient management on growth parameters of maize.**

| Treatments | Plant height (cm) | | | Leaf area ($cm^2$ $plant^{-1}$) | | Dry matter accumulation (g $plant^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | Knee high stage | Tasseling stage | Maturity stage | Knee high stage | Tasseling stage | Knee-high stage | Tasseling stage | Maturity stage |
| **Moisture conservation** | | | | | | | | |
| FB | 39.7 | 159.7 | 177.9 | 1093 | 5144 | 24.9 | 136.7 | 151.9 |
| RB | 40.5 | 162.3 | 183.5 | 1186 | 5308 | 27.0 | 143.9 | 159.4 |
| RBM | 42.9 | 165.1 | 189.3 | 1289 | 5700 | 28.9 | 151.2 | 164.2 |
| SEm± | 0.60 | 3.04 | 2.07 | 27.9 | 67.5 | 0.59 | 1.70 | 1.64 |
| CD (P=0.05) | 2.35 | 11.96 | 8.14 | 107.0 | 265.2 | 2.34 | 6.70 | 6.43 |
| **Integrated nutrient management** | | | | | | | | |
| INM1 | 30.7 | 134.9 | 162.3 | 730 | 3419 | 20. 9 | 118.2 | 136.6 |
| INM2 | 44.5 | 171.6 | 194.1 | 1436 | 6352 | 30.5 | 156.2 | 167.4 |
| INM3 | 43.8 | 169.7 | 180.7 | 1141 | 5310 | 26.5 | 144.0 | 161.2 |
| INM4 | 45.1 | 173.3 | 197.1 | 1449 | 6454 | 29. 9 | 157.4 | 168.7 |
| SEm± | 1.07 | 3.90 | 2.94 | 18.4 | 79.8 | 0.52 | 3.47 | 2.99 |
| CD (P=0.05) | 3.18 | 11.60 | 8.74 | 54.7 | 237.1 | 1.54 | 10.32 | 8.89 |

FB-flat bed; RB-raised bed; RBM-raised bed + mulch (3 t $ha^{-1}$); $INM_1$-control; $INM_2$-RDF100% (150:60:40 kg/ha NPK); $INM_3$-50% RDF + FYM (5 t/ha) + 2% urea spray twice; $INM_4$-50% RDF +FYM (10 t/ha) +2% urea spray twice; INM-integrated nutrient management.

planting recorded significantly lower dry matter accumulation compared to RB at tasseling and maturity stages, but both treatments were similar at knee-high stage. The improvement in these growth characteristics under RBM treatment could be due to the conservation of moisture by reduced evaporation and maintenance of better of soil moisture regimes by mulch cover between two irrigation intervals, which keep soil's biological, physical and chemical environment in ideal condition. Moreover, mulch insulates soil surface from being heated up by direct sunlight and protects the crop from heat stress in summer season (Dass and Bhatacharya, 2017; Gul, 2017). Similarly, Singh *et al*. (2016) reported that application of rice straw mulch 6 t ha enhanced plant height, number of green leaves, dry matter accumulation in dry season maize. Grass, straw and tree biomass mulch adequately supplied moisture which directly and positively influenced the growth parameters of crop and indirectly increased the availability and utilization of nutrients as compared to control (Dass *et al.*, 2013).

Among INM options, 50% RDF+ FYM 10 t/ ha + 2 foliar sprays of urea (2%) registered the maximum values for growth parameters at all growth stages. INM options, 100% RDF, 50% RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%) and 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) did not differ significantly for plant height at knee-high and tasseling stages. However, both the INM options recorded significantly greater plant height over control, the respective increase being 45 and 27.2 %, 42.8 and 25.8% and 46.7 and 28.4% at knee-high and tasseling stage, respectively. At maturity stage, the plants were significantly taller in plots treated with 100% RDF and 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) compared to 50% RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%) and control plots. Among INM options, 100% RDF and 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) remained statistically at par with each other and both depicted significantly higher leaf area compared to 50% RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%) and control plots. The INM options, 100% RDF and 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) recorded on par dry matter accumulation at all growth stages and remained significantly superior to control.

However, 50% RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%) resulted in a significantly lower dry matter production as compared to 100% RDF and 50% RDF+ FYM 10 t ha$^{-1}$ + 2 foliar sprays of urea (2%). Maize is a nutrient exhaustive crop and requires a heavy external application of nutrients (Sharma and Dass, 2012; Ghosh *et al.*, 2017; Kumari *et al.*, 2017), particularly N. Thus reducing nutrient dose to 50% of RDF and applying only 5 t ha$^{-1}$ FYM + urea spray (2%) twice might have not been able to meet the nutrient requirement of maize resulting in significantly low shoot and rrot growth. Whereas, applying a higher FYM dose (10 t ha$^{-1}$) in addition to 50% RDF + urea spray (2%) might have met-out the season-long nutrient needs of maize along with improvement in rhizospheric soil environment and reduction in nutrient losses. Hashim *et al.* (2015) attributed the maximum plant height, dry-matter and LAI of maize with of 50% RDF + 50% RDN from organic sources as organic and inorganic sources of nutrients provided dual purpose of conserving soil moisture and season-long nutrient supply to the crop.

## Grain yield and yield attributes

Yield and yield attributes *viz.*, cobs plant$^{-1}$, grain rows cob$^{-1}$, grains cob$^{-1}$ and 1000-grain weight were significantly influenced by MCP and INM options (Table 2). Raised bed + mulch (3 t ha$^{-1}$) recorded the highest values of all yield attributes as well as grain and straw yields as compared to FB planting system. Yield attributes and straw yield remained statistically at par with RBM and RB planting but grain yield was significantly higher with RBM. This might be due to increase in moisture availability, better utilization of nutrients and cumulative effect of higher values of yield attributes with mulch in RBM planting. Further, the ideal soil moisture conditions in RBM plots might have helped production of larger amount photosynthates, particularly during reproductive phases and translocation of newly synthesized and stored photosynthates from their sites of synthesis and storage to cobs and finally to grains. The increment in grain yield with RB and RBM was 6.1 and 14.5% higher over FB planting. These findings are in accordance with results of Kumar (2015) and Hussain *et al.* (2015).

All INM strategies were found to be significantly superior to control in terms of yield and yield attributes. INM option of 50% RDF+ FYM 10 t ha$^{-1}$ + 2 foliar sprays of urea (2%) registered the significantly higher values of all yield attributes and grain and straw yield as compared to control however, remained

**Table 2. Effect of moisture conservation and integrated nutrient management on yield and yield attributes of maize.**

| Treatments | Cobs plant$^{-1}$ | Grain rows cob$^{-1}$ | Grains cob$^{-1}$ | 1000-grain weight (g) | Straw yield (t ha$^{-1}$) | Grain yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|
| **Moisture conservation** | | | | | | |
| FB | 1.24 | 12.4 | 391 | 169.1 | 6.56 | 4.56 |
| RB | 1.37 | 13.0 | 399 | 173.1 | 6.84 | 4.84 |
| RB + mulch (3t/ha) | 1.47 | 13.8 | 412 | 181.3 | 7.22 | 5.22 |
| SEm± | 0.03 | 0.25 | 4.3 | 2.14 | 0.12 | 0.09 |
| CD (P=0.05) | 0.13 | 0.99 | 17.0 | 8.40 | 0.46 | 0.34 |
| **Integrated nutrient management** | | | | | | |
| INM1 | 1.10 | 10.5 | 255 | 144.2 | 5.48 | 3.31 |
| INM2 | 1.36 | 14.1 | 451 | 185.1 | 7.37 | 5.44 |
| INM3 | 1.38 | 13.4 | 443 | 180.9 | 7.07 | 5.06 |
| INM4 | 1.60 | 14.2 | 456 | 188.8 | 7.59 | 5.69 |
| SEm± | 0.06 | 0.27 | 5.6 | 2.56 | 0.18 | 0.13 |
| CD (P=0.05) | 0.20 | 0.79 | 16.5 | 7.60 | 0.51 | 0.37 |

FB-flat bed; RB-raised bed; RBM-raised bed + mulch (3 t ha$^{-1}$); $INM_1$-control; $INM_2$-RDF100% (150:60:40 kg/ha NPK); $INM_3$-50% RDF + FYM (5 t/ha) + 2% urea spray twice; $INM_4$-50% RDF +FYM (10 t/ha) +2% urea spray twice; INM-integrated nutrient management.

statistically at par with 100% RDF except number of cobs plant$^{-1}$. INM of 50% RDF + FYM 5 t ha$^{-1}$ + 2 foliar sprays of urea (2%) and 100% RDF were recorded at par for yield attributes. Cobs plant$^{-1}$, grain rows cob$^{-1}$ and 1000-grain weight from 50% RDF + FYM 5 t/ha + 2 foliar sprays of urea (2%) were significantly lower as compared to 50% RDF + FYM 10 t ha$^{-1}$ + urea foliar spray (2%) which might be mainly due to dual role of moisture conservation and nutrient supply played by FYM in latter INM option. Both INM options, 50% RDF + FYM 5 t ha$^{-1}$ + 2 foliar sprays of urea (2%) and 50% RDF + FYM 10 t ha$^{-1}$ + 2 foliar sprays of urea (2%), resulted in 52.9 and 71.9% higher grain yield over control, respectively whereas, 100% RDF recorded 64.4% higher grain yield over control. The INM treatments could have increased nutrient availability in sufficient amount consequent to their released into the soil slowly by gradual minerali-zation at a constant rate leading to an increased uptake of nutrient because of the better soil environment created owing to the addition of organic sources combined with inorganic source of nutrient; these positive impacts of INM enhanced the plant growth and consequently enhanced the yield attributes and yield (Hashim *et al.,* 2015).

The use of 100% RDF, 50% RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%) and 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) caused 34.5, 29.0 and 38.5% enhancement in straw yields overall control (5.48 t/ha), respectively. The 50% RDF+ FYM 10 t/ha + 2 foliar sprays of urea (2%) though did not differ from 100% RDF significantly, but showed a significant increase (7.4%) in straw yield over RDF+ FYM 5 t/ha + 2 foliar sprays of urea (2%). Continuous supply of nutrients to the maize plants ensured by the integrated use of fertilizers and FYM might have resulted in the higher straw yield of maize. These results are in line with those of Sarwar *et al.* (2012) and Wailare and Kesarwani (2017) who reported that INM treatments produced significant higher stover yield than sole application of either of them.

## Conclusion

Based on the above research findings it can be concluded that raised bed + mulch planting method was found most suitable in terms of growth and productivity of maize while among INM options 50% RDF + FYM 10 t/ha + urea foliar spray (2%) enhanced the growth and yield traits, which resulted in highest and comparable grain yield with recommended doses of fertilizers. Thus, raised bed + mulch and 50% RDF + FYM 10 t/ha + urea foliar spray (2%) were the most suitable to obtained highest productivity of maize in southern region of Afganistan.

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