ISSN (Online): 2091-2609
DOI Prefix: 10.3126/ijasbt
International Journal of Applied Sciences and Biotechnology
(IJASBT)

Research Article

Response of Nutrient Omission and Irrigation Scheduling on Growth and Productivity of Maize

N.R. Acharya[1*], S.K. Sah[2], A.K. Gautam[3], A.P. Regmi[3]

[1]Nepal Agricultural Research Council, Directorate of Agricultural Research, Khajura, Banke, Nepal
[2]Agriculture and Forestry University, Rampur, Chitwan, Nepal
[3]Nepal Agricultural Research Council, Singh Durbar Plaza, Kathmandu, Nepal

Article Information

Received: 20 August 2020
Revised version received: 23 September 2020
Accepted: 25 September 2020
Published: 29 September 2020

Cite this article as:
N.R. Acharya et al. (2020) Int. J. Appl. Sci. Biotechnol. Vol 8(3): 343-354. DOI: 10.3126/ijasbt.v8i3.31612

***Corresponding author**
Nav Raj Acharya,
Nepal Agricultural Research Council, Directorate of Agricultural Research, Khajura, Banke, Nepal
Email: navraj.dang@gmail.com

Peer reviewed under authority of IJASBT

Abstract

An experiment was conducted for response of nutrient omission to irrigation scheduling in hybrid maize during winter season of 2015 at farmer's field Khajura, Banke where intense summer and severe winter occurs. Soil is sandy loam and climatically humid sub-tropical with average annual rainfall of 1000-1500 mm. The experiment was replicated 3 times with split plot design having plot size of 3 x 3.6 m^2. There were three irrigation level as main plot; (30 -35 DAS, tasseling stage), (30-35 DAS, tasseling, grain filling stage), (tasseling stage) and six level of fertilizer dose as sub-plot; farmer fertilization practice (27.6:27.6:18 N-P-K kg ha^{-1}), recommended dose of fertilizer (160:60:40 N-P-K kgha^{-1}), 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}), N_0PK (60:40 P-K kg ha^{-1}), NP_0K (160:40 N-K kg ha^{-1}), NPK_0 (160:60 N-P kg ha^{-1}). 3 level of irrigation increased the grain yield (4333 kg ha^{-1}) by 33.7% than 2 level of irrigation (3240.6 kg ha^{-1}) and 78.4% than single irrigation (2428.8 kg ha^{-1}). Similarly, 182.4% grain yield could be increased with RDF (4994.9 kg ha^{-1}) than N_0PK (1768.6 kg ha^{-1}). Grain nutrient uptake was recorded 80.4% N (56.3 kg ha^{-1}), 79% P (18.8 kg ha^{-1}), 88.8% K (15.1 kg ha^{-1}) higher with three levels of irrigation than single irrigation N (31.2 kg ha^{-1}), P (10.5 kg ha^{-1}), K (8 kg ha^{-1}) and 184% N (64.6 kg ha^{-1}), 183.7% P (21 kg ha^{-1}) and 188% K (17 kg ha^{-1}) was recorded higher with RDF than (N0PK) N (22.7 kg ha^{-1}), P (7.4 kg ha^{-1}), K (5.9 kg ha^{-1}).

Keywords: NPK omission; irrigation level; maize; nutrient uptake; soil moisture content

Introduction

Maize (*Zea mays* L.) is the only member of the genus *Zea*, under the family Gramineae. It is one of the most efficient crops which can give high biological yield as well as grain yield in a short period of time due to its unique photosynthetic mechanism. Maize grain has greater nutritional value; it contains 72 percent starch, 10 percent protein, 8.5 percent fibre, 4.8 percent oil, 3 percent sugar and 1.7 percent ash (Chaudhary, 1983). It ranks after wheat and rice as the third most important cereal crop in the world considering total area and production. It is the second most important cereal crop after rice in terms of area and production in Nepal. Maize (*Zea mays* L.) is cultivated in 954158 ha area of land and is the second most important cereal crop after rice 1469545 ha area in Nepal (MoALD, 2018). Out of the total cereal production (10012742 Mt) of the country, maize production alone contributes to about 26% (2555847 Mt). The national average productivity of maize is 2679 kg ha^{-1}. Out of the total cereal crops cultivating area 3428986 ha of the nation, maize occupies 27.8% (MoALD, 2018).

Most of the farmers are not attracted towards judicious use of fertilizers due to high costs, uncertainty about the economic returns fertilizing food crops, and more often lack of technical know how about the optimum rate and application time of fertilizers (Hopkins *et al*., 2008). Nutrient deficiency is the major constraint for the development of an economically successful agriculture (Fageria *et al*. 2006). Higgs *et al*. (2002) reported that 30 to 50 percent of the increase in world food production since 1950s is attributable to fertilizer use. Nitrogen uptake occurs maximum during the time prior to tasseling and silking (Hammons, 2009). Nitrogen stress reduced poor kernel formation, increased barrenness and finally low grain yield (Andrade *et al*., 2000). Proper time and supplemental irrigation should be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. Water deficit has little effect on timing of emergence, number of leaves per plant but delayed tasseling initiation and silking, reduced plant height and vegetation growth of maize. All the vital physiological processes of a plant like cell division, cell elongation, cell wall synthesis, NO_3-reductase activity, protein synthesis, photosynthesis, and translocation of assimilates are very sensitive to water stress. This shows that plant water status plays a key role for attaining potential yield by enabling a genetic variable to exploit fully its physical environment. So, one of the biggest problems in crop production over the globe is "how to maintain optimum plant/soil moisture status during crop growing season?" which signifies the scope of irrigation scheduling as a single limiting factor in crop production. The lack of high-yielding and stress tolerant varieties, lower plant populations and lower level of fertilization are the main reasons in farmer's field for the less production of maize. Inadequate knowledge regarding scheduling of irrigation in winter maize and its interaction with nutrient levels is the constraint of improving maize productivity and profitability. This research attempts to address these gaps in knowledge through on-farm experiments in the mid-western region of Nepal. In the terai, inner terai and low-lying river basin areas the maize is grown in the winter and spring with partial irrigation (Paudyal *et. al*., 2001).

Material and Methods

The experiment was carried out at farmer's field of Janaki Gaupalika -4, Khajura, Banke in winter season 2015. The climatic condition of the experimental location was intense summer and intense winter with sandy loam and climatically humid sub- tropical with average annual rainfall of 1000 -1500 mm. It is located at 81° 37" East longitudes and 28° 06" North latitude and an altitude of 181 masl. The maximum and minimum temperature at the site is 46ºC and 5.4ºC respectively, with relative humidity ranging between 27 to 94%. Humidity remains low in most parts of the year. The experiment was replicated 3 times with split plot design having plot size of 3 x 3.6 m^2. Three irrigation times were allotted to main plots and six fertilizer doses with NPK omission plot allotted as sub plots. Row to row spacing for each plot was maintained at 60 cm so that every plot received 6 rows of maize where two outer rows was for destructive sampling, and four rows were net plot. The plant to plant spacing was maintained at 25 cm. The net plot area was 7.2 m^2 consisting of 4 rows of 3-meter length consisting 12 plants row^{-1}. Fertilizer in the form of di–ammonium phosphate (DAP) and murate of potash (MoP) was applied at the time of sowing while half of urea was top dressed at 30 -35 days after sowing and the next half dose was top dressed at the time of tasseling stage. All cultural practices like irrigation, application of herbicides, pesticides and other operations were uniformly carried out. Rajkumar hybrid was sown on 25 October, 2015 at the farmer's field.

Table 1: Treatment details of the experiment

SN	Particulars
Main plot (Irrigation level)	
1	30 -35 DAS + Tasseling stage
2	30 -35 DAS + Tasseling stage + Grain filling stage
3	Tasseling stage
Sub plot (Fertilizer dose)	
1	Farmer practice (27.6:27.6:18 N-P-K kg ha^{-1})
2	Recommended dose (160:60:40 N-P-K kg ha^{-1})
3	50% above recommended dose (240: 90: 60 N-P-K kg ha^{-1})
4	N_0PK (60:40 P-K kg ha^{-1})
5	NP_0K (160:40 N-K kg ha^{-1})
6	K_0NP (160:60 N-P kg ha^{-1})

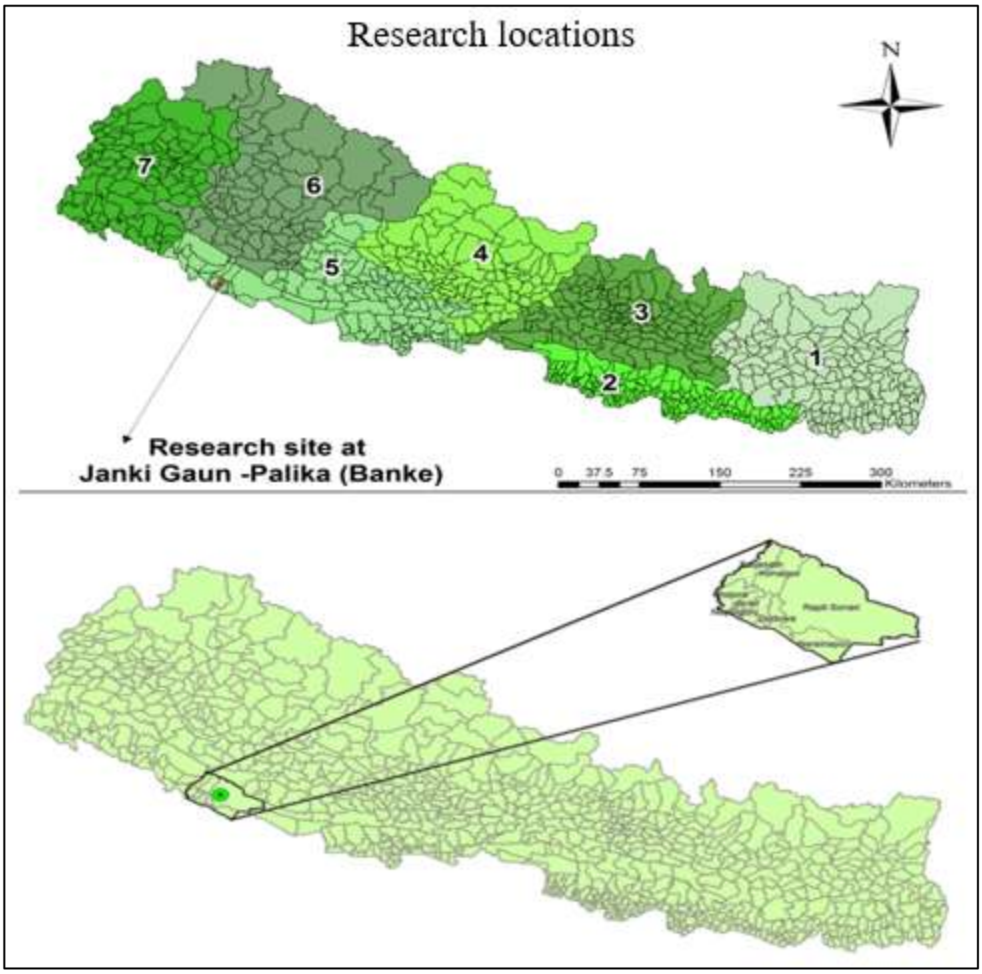

Fig. 1. Location map of the experimental plot

Result and Discussion

Plant Height

The analysis data (Table 2) revealed that the difference in plant height at different time interval influenced by irrigation and fertilizer dose with NPK omission technique at 90 days after sowing was significantly ($p<0.05$) higher (102.6 cm) when the irrigation supplied 3 times (30-35 DAS, tasseling and grain filling stage) followed by (94 cm) from 2 times irrigation supplied (30-35 DAS and tasseling stage) while the least (80.2 cm) height was measured from single irrigation (tasseling stage) supplied plot. At 120 days after sowing, plant height to irrigation was significantly ($p<0.01$) higher (118.3 cm) from 3 times irrigation supplied plot (30-35 DAS, tasseling and grain filling stage) followed by (110.9 cm) from 2 times irrigation supplied (30-35 DAS and tasseling stage) plot. The lowest (89.9 cm) was recorded from single irrigation at tasseling stage but the difference in plant height influenced by fertilizer dose was non–significant. Similar result was also reported by (Sadeghi and Bahrani, 2002) that increase in nitrogen had no significant effect of plant height. But in contrast (Sharma *et al*. 1991) reported a significant increase in the plant height and number of leaves plant^{-1} with successive increase of fertilizer. Similarly, Prasad *et al*. (1987) also reported that increase in maize growth with increasing level of nitrogen application from 0 to 120 kg ha^{-1} and 0 to 150 kg ha^{-1} respectively.

Analysis of data (Table 3) revealed that interaction effect of irrigation with fertilizer dose at 120 days after sowing was significantly ($p<0.05$) higher (145.2 cm) with the interaction effect of potassium omission plot and 2 times irrigation (30 -35 DAS and tasseling stage) which was at par (128.4 cm) with farmer fertilization practice and 3 times irrigation (30 -35 DAS, tasseling and grain filling stage), similarly (126 cm) from potassium omission plot and 3 times irrigation (30 -35 DAS, tasseling and grain filling stage) and (121.9 cm) from phosphorus omission plot and 3 times irrigation (30 -35 DAS, tasseling and grain filling stage) while the lowest (80.9 cm) height was recorded from potassium omission plot with single irrigation (tasseling stage).

Yield Components

Analysis of data (Table 4) revealed that number of plants at harvest ha^{-1}, number of ear harvested ha^{-1} and sterility percentage were non-significant to each level of irrigation though higher number of plants and ears were recorded from three level of irrigation, likewise less irrigation also increased sterility% of the crop. But the number of ears harvested ha^{-1} and sterility percentage significantly ($p<0.001$) influenced by the effect of fertilizer dose with NPK omission plot technique. Higher number of ears (40740.7) was recorded from recommended and 50 percent above recommended dose of fertilizer as compared to other treatments. Under optimum water and nutrient supply, high plant density can result in an increased number of cobs per unit area, with eventual increase in grain yield (Bavec and Bavec, 2002).

Lower (8.1%) sterility was recorded from 50 percent above recommended fertilizer dose and the highest (13.7%) sterility observed from nitrogen omission plot (N_0PK) followed by recommended dose of fertilizer (10.3%), NPK_0 (10.3%), farmer fertilization practice (10.8%) and NP_0K (11.4%). From this result; with adequate nitrogen supply sterility could be reduced. It could be suggested that absence of nitrogen increases sterility and ultimately limits the optimum growth of crop resulting low grain yield and biomass production.

Table 2: Plant height influenced by irrigation and fertilizer dose with NPK omission

	Plant height at 30 days interval from 30 to 150 days after sowing (cm)				
	30	**60**	**90**	**120**	**150**
Main plot: Irrigation					
30 -35 DAS + tasseling stage	34.0	83.0	94^{a}	110.9^{a}	92.9
30 -35 DAS+ tasseling +grain filling stage	34.6	82.3	102.6^{a}	118.3^{a}	100.8
Tasseling stage	35.1	75.7	80.2^{b}	89.9^{b}	84.7
F -test	ns	ns	*	**	ns
LSD (0.05)	-	-	13.7	8.5	-
CV %	22.5	14.6	16.0	8.7	15.5
Sub plot: Fertilizer dose					
Farmer practice	31.9	80.2	91.8	106.3	90.9
Recommended dose	34.0	80.3	89.2	98.7	90.3
50% above recommended dose	36.1	78.9	88.0	102.1	87.8
N_0PK	35.0	80.6	92.1	104.5	93.8
NP_0K	34.1	79.3	95.6	109.4	96.0
NPK_0	36.2	82.6	96.9	117.4	97.9
F -test	ns	ns	ns	ns	ns
LSD (0.05)	-	-	-	-	-
CV %	2.0	12.4	16.6	15.6	11.9
Grand mean	34.6	80.3	92.3	106.4	92.8

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level. Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 3: Plant height at 120 days after sowing of maize influenced by interaction effect of irrigation and fertilizer dose with NPK omission

Treatments	**30 -35 DAS + tasseling stage**	**30 -35 DAS+ tasseling + grain filling stage**	**Tasseling stage**
Farmer practice	102.6^{bcde}	128.4^{ab}	88^{de}
Recommended dose	92.3^{cde}	112.2^{bcd}	91.5^{cde}
50% above recommended dose	90.3^{de}	112.6^{bcd}	103.6^{bcde}
N_0PK	113.2^{bcd}	112^{bcd}	88.3^{de}
NP_0K	121.9^{ab}	118.9^{abc}	87.3^{de}
NPK_0	145.2^{a}	126^{ab}	80.9^{e}
F –test	*		
LSD (0.05)	27.8		
CV %	15.6		
Grand mean	106.4		

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4: Number of plants at harvest, number of ear harvested and sterility% of maize influenced by irrigation and fertilizer dose with NPK omission

Treatment combination	Number of plants at harvest ha^{-1}	Number of ear harvested ha^{-1}	Sterility%
Irrigation			
30 -35 DAS + tasseling stage	64969.1	33796.3	10.6
30 -35 DAS+ tasseling +grain filling stage	65432.1	38734.5	9.4
Tasseling stage	65046.3	31790.1	12.3
F -test	ns	ns	ns
LSD (0.05)	-	-	-
CV %	2.6	25.0	55.7
Fertilizer dose			
Farmer practice	64660.5	33487.6^{b}	10.8^{b}
Recommended dose	65277.8	40740.7^{a}	10.3^{b}
50% above recommended dose	65740.7	40740.7^{a}	8.1^{c}
N_0PK	64969.1	29320.9^{b}	13.7^{a}
NP_0K	65123.4	32407.4^{b}	11.4^{b}
NPK_0	65123.4	31944.4^{b}	10.3^{b}
F -test	ns	***	***
LSD (0.05)	-	4643.3	1.8
CV %	2.5	13.8	17.3
Grand mean	65149.2	34773.6	10.7

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level. Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Grain Yield

The effect of the irrigation and fertilizer dose significantly ($p<0.01$) affected grain yield of maize (Table 5). The grain yield of maize under 3 times irrigation (30 -35 DAS, tasseling, grain filling stage) was significantly higher (4333 kg ha^{-1}) than irrigation supplied 2 times (30 -35 DAS, tasseling) (3240.6 kg ha^{-1}) and (2428.8 kg ha^{-1}) as compared to single irrigation (tasseling stage). The grain yield of maize influenced by three levels of irrigation (30 -35 DAS, tasseling, grain filling stage) recorded 33.7% higher than two level of irrigation (30 -35 DAS, tasseling) and 78.4% higher than single irrigation (tasseling stage). The grain yield of maize was significantly ($p<0.001$) higher (4994.9 kg ha^{-1}) with the application of recommended dose and (4870 kg ha^{-1}) with 50 percent above recommended dose of fertilizer than nitrogen omission (1768.6 kg ha^{-1}) plot. It was 182.4% higher with recommended dose and 173.3% higher with 50 percent above recommended dose of fertilizer than nitrogen omission plot (Table 5). The highest grain yield was observed under surplus irrigation conditions which suggest that a reduced irrigation volume can result in a significantly reduced yield. This indicates that limiting nitrogen reduces light interception decreasing leaf area index resulting in lower grain yield. Higher yield response was obtained for maize with increasing nitrogen application under adequate soil water condition (O'Neil *et al*., 2004). Nour and Lazin (2000) reported that nitrogen and phosphorus combination affected grain yield significantly. Malik *et al*. (1976) also reported that the interaction effect of nitrogen and phosphorus increased grain yield significantly. Amanullah and Khalil (2010) observed that increased level of phosphorus produced higher grain and stover yield that might be due to increase in yield and yield components. Ibrikci *et al.* (2005) reported that the deficiency of phosphorus limited the growth and yield of maize. Singaram and Kothandaraman (1994) also recorded increment in phosphorus increases the yield. Nandal and Agrawal (1991) reported a linear response of maize to nitrogen application up to 200 kg ha^{-1} than that of (0 to 150 kg ha^{-1}). Singh *et al*. (1993) also reported response of increase in maize yield and attributes up to 150 kg ha^{-1} of nitrogen application. Tyagi *et al*. (1998) reported that a grain yield of maize increased from 61 to 137 percent with the increment of nitrogen from 75 to 250 kg ha^{-1} as compared to nitrogen omission soil. Padmaja *et al*. (1999) also reported similar type of findings that the grain and stover yields were increased significantly with the increment in nitrogen level from 0 to 150 kg ha^{-1}. Similar trend of findings were also reported by Singh *et al*. (2000), Suryavanshi *et al*. (2008) and Mahmood *et al*. (2001). Water supply plays a significant role in the utilization of fertilizer active substances especially that of nitrogen. Due to the changing precipitation, the effect of fertilization strongly varies on an annual basis. The irrigation and fertilization research results of Nagy (1995, 1997, 1999) have indicated that irrigation improves the efficiency of fertilization and there is a strong correlation between fertilizer utilization and the water supply of a plant. The irrigation and fertilization experiment results of Hank and Frank (1951) have proved that irrigation increases the efficiency of fertilization. The efficiency of fertilizers also depends on agroecological conditions (Lang, 1981).

Table 5: Grain yield, stover yield and harvest index of maize influenced by irrigation and fertilizer dose with NPK omission

Treatment combination	Grain yield ($kgha^{-1}$)	Stover yield $kgha^{-1}$)	HI%
Main plot: Irrigation			
30 -35 DAS+ tasseling stage	3240.6^{b}	4556.8^{b}	41.1
30 -35 DAS+ tasseling +grain filling stage	4333^{a}	5403.7^{a}	43.5
Tasseling stage	2428.8^{c}	3307.6^{c}	40.5
F -test	**	**	ns
LSD (0.05)	631.2	753.7	-
CV %	20.4	18.4	18.1
Sub plot: Fertilizer dose			
Farmer practice	2577.6^{b}	4194.2^{b}	37.2^{b}
Recommended dose	4994.9^{a}	5870.8^{a}	45.8^{a}
50% above recommended dose	4870^{a}	5798.7^{a}	45.6^{a}
N_0PK	1768.6^{c}	2970.7^{c}	37.1^{b}
NP_0K	2795.2^{b}	3857.4^{b}	40.9^{ab}
NPK_0	2998.4^{b}	3844.5^{b}	43.6^{a}
F -test	***	***	**
LSD (0.05)	734.3	787.5	5.6
CV %	22.8	18.4	14.0
Grand mean	3334.1	4422.7	41.7

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Analysis of data (Table 5) revealed that stover yield of maize was significantly ($p<0.01$) influenced by the effect of irrigation. Stover yield of maize influenced by 3 times irrigation (30 -35 DAS, tasseling, grain filling stage) was 15.6% and 38.7% higher (5403.7 kg ha^{-1}) than 2 times irrigation (30 -35 DAS, tasseling stage) (4556.8 kg ha^{-1}) and irrigation at tasseling stage (3307.6 kg ha^{-1}). Stover yield of maize was significantly ($p<0.001$) influenced by the effect of fertilizer dose. Recommended dose (5870.8 kg ha^{-1}) and 50 percent above recommended dose (5798.7 kg ha^{-1}) were 49.3% and 48.7% higher as compared to nitrogen omission plot (2970.7 kg ha^{-1}). From this result, stover yield could be increased with surplus availability of nitrogen in the soil. Similar result was reported by Nimje and Seth (1988) and Nunes *et al*. (1996) that biomass production increased with increasing nitrogen level.

The harvest index of maize influenced by irrigation was non –significant (Table 5). Harvest index was significantly ($p<0.01$) influenced by the effect of fertilizer dose with NPK omission technique. Higher percentage of harvest index 45.8, 45.6 and 43.6 were recorded from recommended dose, 50 percent above recommended dose and potassium omission plot which was at par with phosphorus omission plot (40.9) as compared to farmer fertilization practice (37.2) and nitrogen omission plot (37.1). Lawrence (2008) also reported higher nitrogen dose increases harvest index in maize. With appropriate N-supply, a fast increase of leaf area in the early phase of development can be promoted, and thus the optimal LAI value can be sustained longer, which means an advantage from the aspect of assimilate flow to the grain yield as well as a favorable harvest index value (Berzsenyi, 1993).

Nutrient Uptake in Stover

Irrigation scheduling significantly ($p<0.05$) influenced stover nitrogen uptake. The highest (42 kg ha^{-1}) nitrogen uptake was recorded with (30-35 DAS, tasseling, grain filling stage) and (30-35 DAS, tasseling stage) (40.6 kg ha^{-1}) while the least (24.5 kg ha^{-1}) with single irrigation (tasseling stage). Irrigation significantly ($p<0.01$) influenced stover phosphorus uptake. The highest (44.7 kg ha^{-1}) phosphorus uptake was recorded with (30-35 DAS, tasseling, grain filling stage) and (30-35 DAS, tasseling stage) (33.8 kg ha^{-1}) while the least (24.8 kg ha^{-1}) with the single irrigation (tasseling stage). Irrigation significantly ($p<0.05$) influenced stover potassium uptake. The highest (21.7 kg ha^{-1}) potassium uptake was recorded with (30 -35 DAS, tasseling, grain filling stage) and (30 -35 DAS, tasseling stage) (19.4 kg ha^{-1}) while the least (11.7 kg ha^{-1}) with the single irrigation (tasseling stage) (Table 6).

Fertilizer dose significantly ($p<0.01$) affected stover nitrogen uptake. The highest (49.8 kg ha^{-1}) nitrogen uptake was recorded with 50 percent above recommended dose (240: 90: 60 N-P-K kg ha-1) and recommended dose (160: 60: 40 N-P-K kg ha^{-1}) (48.7 kg ha^{-1}) and the lowest (22.4 kg ha^{-1}) with nitrogen omission (N_0PK). Fertilizer dose significantly ($p<0.001$) affected stover phosphorus uptake. The highest (46.2 kg ha^{-1}) phosphorus uptake was recorded with 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) and recommended dose (160: 60: 40 N-P-K kg ha^{-1}) (45.6 kg ha^{-1}) while the lowest (20.3 kg ha^{-1}) with nitrogen omission (N_0PK). Fertilizer dose significantly ($p<0.001$) affected stover potassium uptake. The highest (24.9 kg ha^{-1}) potassium uptake was recorded with 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) and recommended dose (160: 60: 40 N-P-K kg ha^{-1}) (22.3 kg ha^{-1}) while the lowest (10.9 kg ha^{-1}) with nitrogen omission (N_0PK) (Table 6).

Nutrient Uptake in Grain

Grain nitrogen uptake was significantly ($p<0.01$) influenced by the main effects of irrigation scheduling. The highest (56.3 kg ha^{-1}) was recorded with three level of irrigation (30 -35 DAS, tasseling, grain filling stage) while the lowest (31.2 kg ha^{-1}) with single irrigation (tasseling stage). Grain phosphorus uptake was significantly ($p<0.01$) influenced by the main effects of irrigation scheduling. The highest (18.8 kg ha-1) was recorded with three level of irrigation (30 -35 DAS, tasseling, grain filling stage) while the lowest (12.7 kg ha-1) and (10.5 kg ha^{-1}) with two level of irrigation (30 -35 DAS, tasseling) and single irrigation (tasseling stage) respectively. Grain potassium uptake was significantly ($p<0.01$) influenced by the main effects of irrigation scheduling. The highest (15.1 kg ha^{-1}) was recorded with three level of irrigation (30 -35 DAS, tasseling, grain filling stage) while the lowest (8 kg ha^{-1}) with single irrigation (tasseling stage) (Table 7).

Grain nitrogen uptake was significantly ($p<0.001$) influenced by fertilizer dose. The highest (64.6 kg ha-1) nitrogen uptake was recorded with recommended dose (160: 60: 40 N-P-K kg ha^{-1}) and (62.9 kg ha^{-1}) with 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) while the lowest (22.7 kg ha^{-1}) with nitrogen omission (N0PK). Grain phosphorus uptake was significantly ($p<0.001$) influenced by fertilizer dose. The highest (21 kg ha^{-1}) phosphorus uptake was recorded with recommended dose (160: 60: 40 N-P-K kg ha^{-1}) and 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) (20 kg ha^{-1}) while the lowest (7.4 kg ha^{-1}) with nitrogen omission (N0PK). Grain potassium uptake was significantly ($p<0.001$) influenced by fertilizer dose. The highest (17 kg ha^{-1}) potassium uptake was recorded with recommended dose (160: 60: 40 N-P-K kg ha^{-1}) and 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) (16.4 kg ha^{-1}) while the lowest (5.9 kg ha^{-1}) with nitrogen omission (N0PK) (Table 7).

Table 6: Nutrient uptake in stover of maize influenced by irrigation and fertilizer dose with NPK omission

Treatment combination	**Stover**		
	Nitrogen uptake (kg ha^{-1})	**Phosphorus uptake (kg ha^{-1})**	**Potassium uptake (kg ha^{-1})**
Main plot: Irrigation			
30 -35 DAS + tasseling stage	40.6^{a}	33.8^{b}	19.4^{a}
30 -35 DAS+ tasseling +grain filling stage	42^{a}	44.7^{a}	21.7^{a}
Tasseling stage	24.5^{b}	24.8^{c}	11.7^{b}
F -test	*	**	*
LSD (0.05)	14.3	7.0	6
CV %	43.4	22	37.1
Sub plot: Fertilizer dose			
Farmer practice	32.9^{b}	33.9^{b}	16.6^{b}
Recommended dose	48.7^{a}	45.6^{a}	22.3^{a}
50% above recommended dose	49.8^{a}	46.2^{a}	24.9^{a}
N_0PK	22.4^{c}	20.3^{c}	10.9^{c}
NP_0K	29.6^{bc}	30.2^{b}	14.6^{bc}
NPK_0	31^{bc}	30.8^{b}	16.1^{b}
F -test	***	***	***
LSD (0.05)	8.9	9.1	4.3
CV %	26	27.6	25.6
Grand mean	35.7	34.4	17.5

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 7: Nutrient uptake in grain of maize influenced by irrigation and fertilizer dose with NPK omission

Treatment combination	Grain		
	Nitrogen uptake (kg ha^{-1})	**Phosphorus uptake (kg ha^{-1})**	**Potassium uptake (kg ha^{-1})**
Main plot: Irrigation			
30 -35 DAS + tasseling stage	42.2^{b}	12.7^{b}	11.4^{b}
30 -35 DAS+ tasseling +grain filling stage	56.3^{a}	18.8^{a}	15.1^{a}
Tasseling stage	31.2c	10.5b	8c
F -test	**	**	**
LSD (0.05)	7.5	3.9	2.9
CV %	18.7	30.3	27.4
Sub plot: Fertilizer dose			
Farmer practice	33.7^{c}	11.1^{b}	9.6^{b}
Recommended dose	64.6^{a}	21^{a}	17^{a}
50% above recommended dose	62.9^{a}	20^{a}	16.4^{a}
N_0PK	22.7^{c}	7.4^{c}	5.9^{c}
NP_0K	39.2^{b}	12.3^{b}	10.1^{b}
NPK_0	36.3^{b}	12.4^{b}	9.9^{b}
F -test	***	***	***
LSD (0.05)	11.6	3.3	2.9
CV %	27.9	24.9	26.4
Grand mean	43.2	14	11.5

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

In other words, grain nutrient uptake was recorded 80.4% nitrogen (56.3 kg ha^{-1}), 79% phosphorus (18.8 kg ha^{-1}) and 88.8% potassium (15.1 kg ha^{-1}) higher with three levels of irrigation (30 -35 DAS, tasseling, grain filling stage) than single irrigation (tasseling stage) nitrogen (31.2 kg ha^{-1}), phosphorus (10.5 kg ha^{-1}) and potassium (8 kg ha^{-1}). Likewise, 184% nitrogen (64.6 kg ha^{-1}), 183.7% phosphorus (21 kg ha^{-1}) and 188% potassium (17 kg ha^{-1}) was recorded higher with recommended dose and 177% nitrogen (62.9 kg ha^{-1}), 170% phosphorus (20 kg ha^{-1}) and 177.9% potassium (16.4 kg ha^{-1}) higher with 50 percent above recommended dose of fertilizer than nitrogen omission plot (N0PK) nitrogen (22.7 kg ha^{-1}), phosphorus (7.4 kg ha^{-1}) and potassium (5.9 kg ha^{-1}).

The higher nutrient uptake from 50 percent above and full dose of fertilizer plot might be due to increase in balanced and surplus nutrient concentration with better plant growth. Nitrogen uptake in grain and stover could be enhanced with increased phosphorus applications (Jiang *et al*., 2006) and potassium application (Saifullah et. al., 2002). The lowest nitrogen uptake (22.7 kg ha^{-1}), phosphorus uptake (7.4 kg ha^{-1}) and potassium uptake (5.9 kg ha^{-1}) in grain and nitrogen uptake (22.4 kg ha^{-1}), phosphorus uptake (20.3 kg ha^{-1}) and potassium uptake (10.9 kg ha^{-1}) in stover were observed in nitrogen omission plot (N_0PK). It could be suggested that absence of nitrogen limits the optimum growth of crop resulting low yield and biomass production. These results are also in accordance with Gheysari *et al.* (2009) who reported that irrigation and nitrogen in maximum amount facilitate to uptake of nitrogen which increase grain yield, biological yield and growth all parameters in maize. The reason behind the higher yield of both winter and spring maize could be attributed to longer duration of crop growth, higher rate of photosynthesis and assimilates utilization (Singh and Zaidi, 1989) and higher efficiency in the uptake and use of nutrients by crops (Shrestha, 2007). Winter maize has been observed to be highly responsive to fertilization, results in healthy crop and also helps in protecting against cold damage. Proper time and supplemental irrigation should be realized in irrigation scheduling for the most effective use of available water in optimizing maize production.

Singh *et al*. (1991) reported that with the successive increment of nitrogen level from 50 kg ha^{-1} to 150 kg ha^{-1} nitrogen uptake by winter maize significantly increased. Bhaskaran *et al*. (1992) also reported same trend of higher NPK uptake with increase in nitrogen. Gaur *et al.* (1992), Shivay *et al*. (1999), Selvaraju and Iruthayaraju (1995) also reported similar findings. Padmaja *et al.* (1999) observed that the increase in nitrogen had a significant effect on the uptake of nitrogen by grain and stover as compared to lower level of fertilization. Phosphorus and potassium uptake by stover and grain also increased with the increased rate of nitrogen. Shivay and Singh (2000), Vadivel *et al.* (2001), Singh and Totawat (2002), Kumar and Singh (2003) reported a significant increase in nitrogen with each successive increase in nitrogen level from 0 to 120 kg ha^{-1}. Various researchers also reported similar findings. Lakshmi (2010), Mercy *et al*. (2012), Venkata Rao (2012) and Reddy *et al.* (2012) reported increase of nitrogen had significant influence on nutrient uptake by grain and stover up to the higher level of 240 kg ha^{-1} nitrogen as compared to lower level of nitrogen.

Soil Moisture Percentage

Soil moisture under irrigation and fertilizer with NPK omission plot were non-significant to each other at every 15 days interval of data recording but the difference in soil moisture with irrigation scheduling was significant ($p<0.05$) at 75 days after sowing (Table 8). Soil moisture under three times irrigation (30 -35 DAS, tasseling and grain filling stage) was 29.2 percent higher (12.3%) than one-time irrigation at tasseling stage (8.7%) which was at par (12%) with two times irrigation (30 -35 DAS, tasseling stage). Irrigation at frequent interval improves the soil carbon. Improvement in soil carbon increases the water holding capacity of the soil (Fabrizzi *et al*., 2005; Mupangwa *et al*., 2007). Maize yield development is sequential process in which the potential number of ears plant^{-1} is determined first, followed by grain number per inflorescence and by grain size. Therefore, variations in the level of carbon and nitrogen induced by different planting rates or any other factor can strongly influence yield and its components sequentially (Jacobs and Pearson, 1991). The amount of precipitation, or the moisture stored in the soil, modifies the need and effect of fertilizers. Fertilizer effect increases when activities leading to optimal water supply and decreases when reaching harmful levels of excess water (Nagy, 1994). Fertilization is decisive both in macro and micro element uptake (Nemeth and Buzas, 1991).

Interaction effect of irrigation and fertilizer dose at 120 days after sowing of soil moisture content indicated that interaction of 50 percent above recommended dose (240: 90: 60 N-P-K kg ha^{-1}) with three times irrigation (30 -35 DAS, tasseling, grain filling stage) resulted in higher moisture (18.5%) as compared to other treatment combination (Table 9). Carbon accumulates in the soil only when nitrogen balance is positive (Bayer *et al*., 2000; Sisti *et al*., 2004; Alves *et al*, 2006). It could be due to positive nitrogen balance from sufficient application of nitrogen and surplus irrigation provide to the experimental field.

Table 8. Soil moisture content influenced by irrigation and fertilizer dose with NPK omission

Treatment combination	**Soil moisture at 15 days interval from 45 to 120 DAS (%)**					
	45	**60**	**75**	**90**	**105**	**120**
Main plot: Irrigation						
30 -35 DAS + tasseling stage	10.9	12.2	12^{a}	8.1	9	13.7
30 -35 DAS+ tasseling +grain filling stage	9.9	13.8	12.3^{a}	9.9	7.9	13.4
Tasseling stage	9.7	8.9	8.7^{b}	8.2	6.7	14.9
F -test	ns	ns	*	ns	ns	ns
LSD (0.05)	-	-	2.0			
CV %	25.3	50.7	20.2	25.3	37.5	25
Sub plot: Fertilizer dose						
Farmer practice	10	11.8	11.6	9.2	7.8	13.1
Recommended dose	10.4	12.5	11.2	8.3	7.9	13.8
50% above recommended dose	10	11.3	10.9	9.2	8.6	13.6
N_0PK	9.9	12.2	10.2	8.7	7.2	14.1
NP_0K	9.9	10.6	10.8	8.9	8.4	13.9
NPK_0	10.8	11.5	11.1	8.2	7.2	15.2
F -test	ns	ns	ns	ns	ns	ns
LSD (0.05)	-	-	-	-	-	-
CV %	18.9	23.7	20	23.4	29.5	22.3
Grand mean	10.2	11.7	11.0	8.8	7.9	14.0

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 9. Soil moisture (%) at 120 DAS influenced by interaction effect of irrigation and fertilizer dose with NPK omission

Treatment combination	**30 -35 DAS + tasseling stage**	**30 -35 DAS+ tasseling +grain filling stage**	**Tasseling stage**
Farmer practice	11.4^{c}	13^{bc}	14.9^{abc}
Recommended dose	13.5^{abc}	13.1^{bc}	15^{abc}
50% above recommended dose	10.9^{c}	18.5^{a}	11.4^{c}
N_0PK	13.4^{abc}	11.6^{c}	17.2^{ab}
NP_0K	15.7^{abc}	11^{c}	15.1^{abc}
NPK_0	17.1^{ab}	13^{bc}	15.6^{abc}
SEm(±)	9.8		
F –test	*		
LSD (0.05)	-		
CV %	22.3		
Grand mean	14		

Note: Treatment means followed by common letter(s) within columns are not significantly different among each other at 5% level .Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Conclusion

A research was conducted at the farmer's field of Khajura, Banke for the response of nutrient omission to irrigation scheduling in hybrid maize during winter season. Three level of irrigation; 30 -35 days after sowing, tasseling and grain filling stage increased the yield by 78.4% than single irrigation at tasseling stage and 182.4% by applying recommended dose (160: 60: 40 N-P-K kg ha^{-1}) than with nitrogen omission. Nutrient uptake was also higher 80.4% (nitrogen), 79% (phosphorus) and 88.8% (potassium) in grain and 71.4% (nitrogen), 80.2% (phosphorus) and 85.4% (potassium) in stover with 3 level of irrigation (30 -35 days after sowing, tasseling and grain filling stage) than single irrigation at tasseling stage. Similarly, 184.5% (nitrogen), 183.7% (phosphorus) and 188% (potassium) in grain and 117.4% (nitrogen), 127.5% (phosphorus) and 104.5% (potassium) in stover with recommended dose (160: 60: 40 N-P-K kg ha^{-1}) of fertilizer than nitrogen omission. From this research, we can conclude that nitrogen was the most limiting nutrient for growth and yield of maize followed by phosphorus and potassium at recommended amount and irrigation at proper critical time at 30 -35 days after sowing, tasseling and grain filling stage also enhance the growth and productivity of maize.

Authors' Contribution

N.R. Acharya, S.K. Sah, A.K. Gautam, A.P. Regmi designed the research plan; N.R. Acharya performed experimental works, collected, analysed the data & prepared the manuscript. All authors critically revised, finalized & approved the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

References

Alves BJR, Zotarelli L, Fernandes FM, Heckler JC, Macedo RAT, Boddy RM, Jantalia CP and Urquiaga S (2006) Biological nitrogen fixation and nitrogen fertilizer on the nitrogen balance of soybean, maize and cotton. *Pesq Agrop Bras* **41**(3): 449-456. DOI: 10.1590/S0100-204X2006000300011

Amanullah ZM and Khalil SK (2010) Timing and rate of P application influence maize phenology, yield and profitability in Northwest Pakistan. *International Journal of Plant production* **4**: 281-292.

Andrade FH, Ortegiu ME and Vega C (2000) Intercepted Radiation at Flowering and Kernel Number in Maize. *Agronomy Journal* **92**: 92-97. DOI: 10.2134/agronj2000.92192x

Bayer C, Martin-Neto L, Mielniczuck J and Ceretto CA (2000) Effect of no tillage cropping system on soil organic matter in a sandy clay loam Acrisol from southern Brazil monitored by electron spin resonance and nuclear magnetic resonance. *Soil and Tillage Research*, 53: 95-104. DOI: 10.1016/S0167-1987(99)00088-4

Bhaskaran S, Kandaswamy P and Manickam TS (1992) Effect of N levels and soils on the N P K uptake by maize. *Madras Agril J* **79**(11): 623-627.

Chaudhry AR (1983) *Maize in Pakistan*. Punjab Agriculture Co-ordination Board, University of Agriculture Faisalabad.

Fabrizzi KP, Gracia FO, Costa JL & Picane LI (2005) Water dynamics, physical properties and corn and wheat responses to minimum and no tillage system in the Southern Pampos of Argentinan. *Soil and Tillage Research* **81**: 57-69. DOI: 10.1016/j.still.2004.05.001

Fageria K, Baligar VC and Clark RB (2006) *Physiology of crop production*. NewYork: The Haworth Press. DOI: 10.1201/9781482277807

Gaur BL, Mansion PR and Gupta DC (1992) Effect of nitrogen levels and their splits on yield of winter maize (*Zea mays* L.). *Indian J Agron* **37**(4): 816-817.

Gheysari M, Mirlatifi SM, Bannayan M, Homaee M and Hoogenboom G. (2009) Interaction of water and nitrogen on maize grown for silage. *Agriculture water management* **96**(5): 809-821. DOI: 10.1016/j.agwat.2008.11.003

Hammons JL (2009) *Nitrogen and Phosphorus Fertilization of Corn*. Virginia cooperative Extension. Publication 424-027.

Hank O and Frank M. (1951) *Correlation between soil nutrient supply and water consumption in specific plants*. OKI Evkonyv, Szarvas.

Higgs B, Johnston, AE, Salter JL and Dawson CJ (2002) Some aspects of achieving phosphorus use in agriculture. *Journal of Environmental Quality* **29**: 80–87. DOI: 10.2134/jeq2000.00472425002900010010x

Hopkins BG, Rosen CJ, Shiffler AK and Taysom TW. (2008) *Enhanced efficiency fertilizers for improved nutrient management of potato*. University of Idaho, Aberdeen. DOI: 10.1094/CM-2008-0317-01-RV

Ibrikci H, Ryan J, Ulger AC, Buyuk G, Cakir B, Korkmaz K, Karnez E, Ozgenturk G and Konuskan O (2005) Maintenance of P fertilizer and residual P effect on corn production. *Nigerian Journal of Soil Science* **2**: 279-286. DOI: 10.1007/s10705-005-3367-8

Jiang ZQ, Feng CN, Huang LL, Guo WS, Zhu SK and Peng YX (2006) Effects of phosphorus application on dry matter production and phosphorus uptake in wheat. *Plant Nut Fert Sci* **12**(5): 628-634.

Krishnaveni K and Ramaswamy KR (1985) Influence of N, P and K on the seed yield and yield attributes of CH-1maize hybrid. *Madras Agricultural Journal* **72**(7): 382-387.

Kumar M and Singh M. (2003) Effect of nitrogen and phosphorus levels on yield and nutrient uptake in winter maize (*Zea mays* L.) under rainfed conditions of Nagaland. *Crop Res* **25**(1): 46-49.

Lakshmi NV (2010) *Nitrogen requirement of rice fallow maize (Zea mays L.) as influenced by nitrogen management in* *rice*. Ph. D Thesis, Acharya N G Ranga Agricultural University, Hyderabad, India.

Lang I (1981) Report on the national survey results of agroecological potential. Agrartudomanyi Kozl., *Budapest* **40**: 29-98.

Lawrence JR, Ketterings, QM and Cherney JH (2008) Effect of nitrogen application on yield and quality of corn. *Agronomy Journal* **100**(1): 73-79. DOI: 10.2134/agronj2007.0071

Mahmood MT, Maqsood M, Awan TH, Rashid S and Sarwar R (2001) Effect of different levels of nitrogen and intra-row plant spacing on yield and yield components of maize. *Pak J Agril Sci* **38**: 48-49.

Malik A, Negm SH and Bachata MA (1976) Corn yield as affected by NPK fertilization calcareous soil. *Agriculture research revision* **52**: 57-61.

Mercy Z, Chandrasekhar K and Subbaiah G (2012) Response of maize (*Zea mays* L.) to planting densities and nitrogen levels under late *rabi* conditions. *Andhra Agril J* **59**(4): 517-519.

Mupangwa W, Twomlow S, Walker S and Hove I (2007) Effect of minimum tillage and mulching on maize (*Zea mays* L) yield and water content of clayey and sandy soils. *Phys Chem Earth* **32**: 1127-1134. DOI: 10.1016/j.pce.2007.07.030

Nagy J (1994) *The effect of fertilization and irrigation on the yield of maize (Zea mays L.) hybrids with various genotypes*. Unipress, Padova, 421-440.

Nagy J (1995) Evaluating the effect of fertilization on the yield of maize (*Zea mays* L.) in different years. *Novenytermeles* **44**(5-6): 493-506.

Nagy J (1997) The effect of fertilization on the yield of mays (*Zea mays* L.) in unirrigated and irrigated cultivation. *Agrokemiaes Talajtan*, **46**(1-4): 275-288.

Nagy J (1999) Evaluation of interaction between irrigation and soil cultivation in maize production. *Acta Agronomica* **47**(2): 181-190.

Nandal DPS and Agarwal SK. (1991) Response of winter maize to sowing dates, irrigation and nitrogen. *Indian J Agron* **36**(2): 239-242.

Nemeth, T and Buzas I. (1991) Long term nitrogen fertilization experiment on Nitrogentragyazasi tartamkiserlet humuszos homok-esmeszlepedekes csernozjom talajon. *Agrokemia es Talajtan*, **40**: 399-408.

Nimje PM and Seth J (1988) Effect of nitrogen on growth, yield and quality of winter maize. *Indian J Agron* **33**(2): 209-211.

Nour AM and Lazin ME. (2000) Annual report, maize research program agricultural research corporation ministry of agriculture and forestry, Sudan.

Nunes GHS, Silva PSL and Nunes SGH. (1996) Responses of maize to nitrogen levels and weed control. *Ciencia-e-Agrotechnologia*.**20**: 205- 211.

O'Neill, PM, Shanahan JF, Schepers JS and Caldwell B. (2004) Agronomic responses of corn hybrids from different eras to deficit and adequate levels of water and nitrogen. *Agronomy Journal* **96**: 1660-1667. DOI: 10.2134/agronj2004.1660

Padmaja M, Srilatha D and Rao KL. (1999a) Effect of nitrogen on nutrient uptake in maize (*Zea mays L.*) types. *J Res ANGRAU* **27**(4): 112-114.

Prasad VK, Thakur HC, Pandey SS, Pandey RO and Sharma NN (1987) Effect of irrigation and nitrogen on winter maize in calcareous saline alkali soil. *Indian J Agron* **32**(3): 217-220.

Reddy MM, Padmaja B and Reddy DVV (2012) Response of maize (*Zea may*s L.) to irrigation scheduling and nitrogen doses under no-till condition in rice fallows. *J Res ANGRAU* **40**(1): 6-12.

Sadeghi, H and Bahrani MJ (2002) Effects of plant density and N rates on morphological characteristics and protein contents of corn. *Iranian Journal of Agriculture Science* **33**: 403-412.

Saifullah A, Ranjha M, Yaseen M and Akhtar MF. (2002) Response of wheat to potassium fertilization under field conditions. *Pak J Agric Sci* **39**(4): 269-272.

Selvaraju R and Iruthayaraju MR (1995) Effect of irrigation, methods of irrigation and nitrogen levels and nutrient uptake by maize (*Zea mays* L.). *Madras Agril J* **82**(3): 216-216.

Sharma KN, Bhandari AL, Kapur ML and Rana DS (1991) Nitrogen use efficiency patterns in four cultivars of hybrid maize. *J Res Punjab Agril Uni* **28**(1): 16-19.

Shivay YS and Singh RP (2000) Growth, yield attributes, yield and nutrient uptake of maize (*Zea mays* L.) as influenced by cropping systems and nitrogen levels. *Ann Agril Res* **21**(4): 494-498.

Shrestha J (2007) *Growth and productivity of winter maize under different levels of nitrogen and plant population*. Thesis, M.Sc., Institute of Agriculture and Animal Science, Rampur. pp. 7-8.

Singaram P and Kothandaraman GV (1994) Studies on residual, direct and cumulative effect of phosphorus sources on the availability, content and uptake of phosphorus and yield of maize. *Madras Agriculture research* **81**: 425-429.

Singh A, Vyas AK and Singh (2000) Effect of nitrogen and zinc application growth, yield and net returns of maize. *Ann Agril Res* **21**(2): 296-297.

Singh CP, Sharma NN and Prasad UK. (1991) Response of winter maize (*Zea mays*) to seeding date, seed - furrow mulching and fertilization with nitrogen, phosphorus and potassium. *Indian J Agril Sci* **61**(12): 889-892.

Singh J, Dhindwal AS, Malik S and Poonia SR. (1993) Effect of irrigation regime and nitrogen on winter maize under shallow water table condition. *J Water Manag* **1**(1): 22-24.

Singh R and Totawat KL (2002) Effect of integrated use of nitrogen on the performance of maize (*Zea mays* L.) on *haplustalfs* of sub-humid southern plains of Rajasthan. *Indian J Agril Res* **36**(2): 102-107.

Singh RP and Zaidi PH. (1989) Technology for increasing production of winter maize in India. *Ind. Far* **48**(1): 42-46.

Sisti CPJ, dos Santos HP, Kohhann R, Alves BJR, Urquiaga S and Boddey RM. (2004) Change in carbon and nitrogen stocks in soil under 13 years of conventional or zero tillage in Southern Brazil. *Soil Till Res* **76**: 39-58. DOI: 10.1016/j.still.2003.08.007

Suryavanshi VP, Chavan BN, Jadhav VT and Baig MIA. (2008) Response of maize to nitrogen and phosphorus application in vertisols. *Int J Trop Agric* **26**(3-4): 293-296.

Tyagi RC, Singh D and Hooda IS. (1998) Effect of plant population, irrigation and nitrogen on yield and its attributes of spring maize (*Zea mays*). *Indian J Agron* **43**(4): 672-676.

Vadivel N, Subbian P and Velayutham A (2001) Effect of integrated nitrogen management practices on growth and yield of rainfed winter maize (*Zea mays* L.). *Indian J Agron* **46**(2): 250-254.

Venkata Rao P (2012) Effect of plant density and N P rates on productivity of rice-fallow maize under zerotillage conditions. *Ph. D Thesis*, Acharya N G Ranga Agricultural University, Hyderabad, India.