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Short term effects of manure and irrigation application on soil nutrients content, water use efficiency and maize productivity in Chitwan, Nepal

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ABSTRACT

A field experiment was conducted at Chitwan, Nepal to evaluate the effects of manure and irrigation application on soil nutrients content, water use efficiency and maize productivity. The experiment was laid out in a factorial complete randomized block design with three replications. The treatments were consisted of two manure levels: no manure and manure with fertilizer based on 120 kg ha^{-1} nitrogen recommended. Similarly, another factor was irrigation water application with five levels which were control (no irrigation) and irrigation applications of 300, 600, 900 and 1200 mm during growing period. The manure application significantly affected the total nitrogen (0.13%) and available phosphorus (37.5 kg ha^{-1}) content in the soil. Interestingly, different irrigation treatments enhanced soil nutrient content differently except soil nitrogen. Similarly, the highest grain yield was observed on 1200 mm irrigation which corresponded to 169% increment over control irrigation treatment but not significant with 600 and 900mm irrigation. The 1200 mm irrigation showed the lowest irrigation water use efficiency (IWUE) (5.96 kg ha^{-1} mm^{-1}), while 300 mm irrigation showed maximum (18.37 kg ha^{-1} mm^{-1}) followed by 600 mm irrigation (7.04 kg ha^{-1} mm^{-1}) based on grain yield. In conclusion, it seems that 600 mm irrigation treatments are quite suitable for the maize production in spring season with benefits of increasing IWUE and saving water around 50% of water which will help in growing more areas and in managing the limited water resources in Chitwan, Nepal.

INTRODUCTION

Globally, agriculture is the main user of water. However, because of the increase in demand from other users and the occurrence of drought in many countries, the resource has become scarce and limited. In Nepal, rainfed crop production is widely practiced with less emphasis on supplemental irrigation. Approximately 40 percentage of the total cultivated area receives some form of irrigation (MoAC 2012). High demand from the ever-increasing population and expansion of irrigated areas put pressure on the water resources. Despite this progressive water shortage, some of the small farmers continue to use flood irrigation that results in high water loss by evaporation and drainage. USGS (2008) showed that over 45% of water applied is lost to deep soil drainage, evapotranspiration and surface runoff. The limited and expensive available water supply makes it impractical to irrigate the entire irrigable land area. To increase the area of irrigated land and to increase overall crop production in Nepal using the same amount of available water, options that save water and improve yield (land productivity) need to be developed. One of these potential options is deficit irrigation (DI) which is the application of a fraction of crop water requirements (English 1990) that maximizes water productivity. The determination and analysis of the agricultural water use index in Nepal are essential to find suitable methods for better and economical use of water for agriculture. Thus, field data such as crop yield, different levels of water use, and irrigation management practices are necessary and pertinent to formulating of water resources polices for better soil management and optimal agricultural production. Effective water management can increases nutrient availability, transformation of

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nutrients in soil or from fertilizers. Mineralization of organic N is proportional to soil water and the net mineralized nitrate N is increased with the increase of water content in an adequate range (Li et al. 2009). Water influences mineral nutrient movement from soil to roots and then from roots to aboveground parts of plants (Li et al. 2009). Water affects original nutrient transformation in soil turning unavailable nutrients into available forms. Water stress influences the availability of nutrients to crop plants and thus total uptake amount. In general water stress reduces both plant growth and nutrient uptake, but reduction rate of net assimilation is more serious than nutrients, leading to a relative increase in nutrient concentration (Li et al. 2009). Marschner (1986) pointed out that in any case, water supply changes resulted in corresponding changes in distribution of roots in the soil profile and nutrient uptake amounts from different layers.

Organic nutrient sources are important components of the nutrient cycle in agro-ecosystems and could be utilized where they are cost efficient and available (Stockdale et al. 2006). Effect of organic manure application on soil quality and crop yield generally became clearer after several years of continuous application. Organic manures may increase soil fertility and thus the crop production potential, possibly by changes in soil physical and chemical properties including nutrient bioavailability, soil structure, water holding capacity, cation exchange capacity, soil pH, microbial community and activity etc. (Marschner 1995; Agbede et al. 2008; Muhammad and Kattak 2009). Hegde (1998) reported that use of costly chemical fertilizers can be minimized or replaced by the use of locally available organic manures. Further, integrated use of organic and inorganic manures sustains the productivity of soil and crops in integrated cropping systems. This approach restores and sustains soil health and productivity in long run besides meeting the nutritional deficiencies (Satyajeet et al. 2007).

Maize (*Zea mays* L.) is one of the most important cereal crops in the world agricultural economy (Peter 2014) which cultivated in all the agro ecological zones in Nepal (CBS 2001). It is important staple food crop of hills and placed second after rice in Nepal. Its yield on farmers' fields is low averaging 2.28 t ha^{-1} compared to potential yields of 6 t ha^{-1} (NARC 2013). The causes of yield gap include improper use of irrigation water, less use of organic manure and imbalance chemical fertilizer are recognized as major problems of low productivity of maize in Nepal. Maize is an efficient user of water and nutrients in terms of total dry matter production and among cereals; it is potentially the highest yielding grain crop. Therefore, it is important to assess the effects of manure and irrigation applications on soil nutrients content, water use efficiency and maize productivity.

MATERIALS AND METHODS

The experiment was conducted at Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal during 2013 (latitude: 27^{0}38' N; longitude: 84^0 20' E,256 masl).The soil at the site is sandy loam texture with a field capacity of 0.181 m m^{-3}, permanent wilting points of 0.07 m m^{-3}, and saturation point of 0.49 m m^{-3}. The particle size distribution is 63% sand, 28.2% silt and 8% clay with 1.25 % soil organic carbon, 0.11 % N, available P 19.13 kg ha^{-1}, exchangeable K 21 kg ha^{-1}in the topsoil (0-15cm). The experiment was conducted with spring maize planting in 75 cm x 25 cm dimension. Pesticide, insecticide and fungicide applications were uniformly applied to the ntire field when needed. The soil nutrient contents of top soil (0-15 cm) were determined at before sowing and after crop harvest in laboratory. Soil organic carbon was analyzed by Walkley and Black tirtration method (Walkey and Black 1934), Soil nitrogen by Kjeldahl distillation method (Bremner and Mulvaney 1982), Available phosphorus by Modified Olsen bicarbonate method (Olsen et al. 1954) and Exchangeable potassium by Ammonium Acetate method (Jackson 1973). Irrigation water use and grain yield of respective treatment was used to compute the irrigation water use efficiency by following formula:

$$\text{Irrigation water use efficiency based on grain yield (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Total grain yield (kg ha}^{-1}\text{ mm}^{-1})}{\text{Irrigation water use (mm)}}$$

There was a manure factor (M) with two levels based on N recommended viz. no manure indicated only fertilizers application of 120 kg ha^{-1} N and with manure application indicated manure and fertilizers application. Organic manures (FYM) were added to soil with 10 t ha^{-1} as recommended 15 days before sowing to the corresponding treatments. By considering 50% N mineralization, nitrogen contribution from manure was calculated on dry weight basis, which of remaining nitrogen was supplemented by inorganic fertilizer (Urea and Di-ammonium Phosphate (DAP) to make 120 kg ha-1 N in manure applied treatments. Half dose of nitrogen, full dose 60 kg ha^{-1} P_2O_5 and 40 kg ha^{-1} K_2O_5 were applied as basal in all plots and remaining nitrogen was applied at 35 DAS. P and K contributed by organic manure were taken in consideration. Phosphorous and Potassium were applied through DAP and Muriate of Potash (MOP) fertilizers respectively. Similarly, another factor was irrigation water application (I) with five levels which were control (no irrigation), 300, 600, 900 and 1200 mm during growing period. Water applied was measured at the plot level by means of a water-discharged (L/s) from the siphon (volumetric method). Each treatment was replicated three times, distance between the replication and plots were maintained 2m and 1.5m respectively with bund to control lateral water movement. Aforementioned irrigation water volumes were planned to apply at 7 different crop stages based on crop water requirement at 15 days interval. But, last irrigation application was not applied due to rainfall. Therefore, total irrigation water volumes applied was 270, 540, 810 and 1080 mm to respective 300, 600, 900 and 1200 mm treatments.

RESULTS AND DISCUSSION

The manure applied treatment had organic carbon of 1.51% and without manure treatment showed 1.36% which were consistent after crop harvest. This result was supported by several researchers (Hati et al. 2007; Manna et al. 2007 and Fening et al. 2011). Similarly, soil exchangeable K content was consistent due to manure application. The reason behind not change in organic carbon might be due to short term experiments along with slow and negligible decomposition and humus formation process of organic manure. However, soil nitrogen and available P were significantly varied with highest value of 0.127 % and 37.5 kg ha^{-1} respectively on manure addition treatment. These results were in agreement with Stamatiadis et al. (1999) and Sounare et al. (2003) that N mineralization and its availability was 40-50% on manure in the first year and in addition to supplemented chemical Nitrogenous fertilizer responsible for increment in soil N residue. Similarly, grain yield was not significant by manure application. It might be due to nutrients supplied by manure was not sufficient to exploit the genetic potential of crops (Subedi and Sapkota 2001).

Soil Organic Carbon, Nitrogen, Phosphorus and Potassium contents under no irrigation condition and 300, 600, 900 and 1200 mm irrigation application throughout the growing season are presented in Table 1. Soil organic carbon concentration after maize harvest revealed that 300 mm irrigation treatments showed 20% higher soil organic carbon content followed by 17.77 % on 1200 mm of irrigation water treatment over no irrigated plots. However, other irrigation treatments 600 and 900 mm irrigation applications were 3.7 % and 2.22 % less organic carbon contents over no irrigated plot respectively. It is generally believed that optimum aeration and moisture in soil increased the oxidation of organic matter in soil and rapid the crop residue decomposition (Reocosky et al. 1995) that resulting to the loss of organic carbon from soil through CO_2 evolution. The maximum residual soil N (0.134%) was found on no irrigated plot which was 9.7, 12.68, 13.43 and 14.18 % higher over 300, 600, 900 and 1200 mm irrigation treatments respectively which were non-significant to each other. This might be due to significantly low biomass production severely restricted by no irrigated plot which in turn resulted in low N uptake and high residual N on soil. Li et al. (2009) revealed that application of water increased nutrient availability, transformation of nutrients in soil or fertilizers. Mineralization of organic N was proportional to soil water and influences the N mineral movement and uptake by plants (Song and Li 2006).

The highest available phosphorus (40.2 kg ha^{-1}) was recorded on 900 mm irrigated plot which was 22.56% more over no irrigated treatment followed by 35.0, 37.7 and 33.6 kg ha^{-1} for 300, 600 and 1200 mm irrigated treatments respectively. Boateng et al. (2006) stated that, increased in soil

Table1. Effects of manure and irrigation applications on soil organic carbon, nitrogen, phosphorus and potassium content of soil

Treatments	Soil Nutrient content in 0-15 cm soil			
	Soil organic Carbon (%)	Soil N (%)	Available P (kg ha^{-1})	Exchangeable K (kg ha^{-1})
Manure (M)				
No manure	1.36 (0.204)	**0.115^{b}** (0.011)	**34.2^{b}** (4.31)	58.6 (23.42)
With manure	1.51 (0.257)	**0.127^{a}** (0.012)	**37.5^{a}** (2.99)	65.0 (23.27)
$LSD_{0.05}$	Ns	0.007	2.1	Ns
SEm±	0.0561	0.0025	0.7	5.2
Irrigation levels (I)				
No irrigation	**1.35^{abc}** (0.304)	**0.134^{a}** (0.016)	**32.8^{c}** (2.59)	**37.2^{c}** (16.01)
300 mm of irrigation water	**1.62^{a}** (0.155)	**0.121^{b}**(0.009)	**35.0^{bc}** (4.36)	**50.9^{bc}** (10.31)
600 mm of irrigation water	**1.30^{c}**(0.201)	**0.117^{b}**(0.01)	**37.7^{ab}** (2.82)	**66.9^{ab}** (11.18)
900 mm of irrigation water	**1.32^{bc}** (0.056)	**0.116^{b}** (0.006)	**40.2^{a}**(2.60)	**71.4^{ab}** (22.37)
1200 mm of irrigation water	**1.59^{ab}**(0.247)	**0.115^{b}** (0.013)	**33.6^{c}** (2.93)	**82.9^{a}** (24.12)
$LSD_{0.05}$	0.26	0.011	3.3	24.38
SEm±	0.0887	0.004	1.1	8.2
CV%	15.12%	7.95%	7.5%	19.07%
Grand mean	1.437	0.121	35.847	61.843

The mean followed by the same letter(s) in a column are not significant different at 5% levels of significance. Means within a column that are not **boldface** are not significantly different. The figures in parenthesis indicate standard deviation of mean within three replications.

Table 2. Interaction effects of manure and irrigation applications on soil organic carbon and nitrogen, content of soil

Treatments	Soil organic Carbon (%)		Soil N (%)	
	No manure	With manure	No manure	With manure
No irrigation	1.203 (0.316)	1.503 (0.254)	12.593 (0.02)	14.287 (0.007)
300 mm of irrigation water	1.543 (0.125)	1.693 (0.172)	11.667 (0.006)	12.433 (0.011)
600 mm of irrigation water	1.287 (0.083)	1.317 (0.305)	11.013 (0.008)	12.413 (0.004)
900 mm of irrigation water	1.287 (0.046)	1.353 (0.046)	11.363 (0.003)	11.8 (0.007)
1200 mm of irrigation water	1.49 (0.201)	1.693 (0.286)	10.673 (0.002)	12.363 (0.014)
Analysis of variances				
	P-value	SEm	P-value	SEm
M x Is	ns	0.125	ns	0.125
CV%	15.12%		7.95%	

The mean followed by the same letter(s) in a column are not significant different at 5% levels of significance. The figures in parenthesis indicate standard deviation of mean within three replications.

Table 3. Interaction effects of manure and irrigation applications on available phosphorus and exchangeable potassium content of soil

Treatments	Available P (kg ha^{-1})		Exchangeable K (kg ha^{-1})	
	No manure	With manure	No manure	With manure
No irrigation	30.8 (1.83)	34.8 (1.20)	34.9 (13.70)	39.5 (7.91)
300 mm of irrigation water	33.2 (5.98)	36.8 (1.39)	48.6 (13.70)	53.2 (7.91)
600 mm of irrigation water	35.7 (1.67)	39.6 (2.4)	62.3 (13.70)	71.4 (7.91)
900 mm of irrigation water	39.6 (2.40)	40.8 (3.17)	66.9 (20.93)	76 (27.40)
1200 mm of irrigation water	31.6 (2.50)	35.6 (1.83)	80.6 (31.64)	85.1 (20.93)
Analysis of variances				
	P-value	SEm	P-value	SEm
M x Is	ns	1.6	ns	11.6
CV%	7.50%		19.07%	

The mean followed by the same letter(s) in a column are not significant different at 5% levels of significance. The figures in parenthesis indicate standard deviation of mean within three replications.

moisture up to certain limits improved P availability in soil thorough organic ligand formation by microbial activity and might be responsible for desorption of P from mineral compounds (Marschner 1995) .Soil exchangeable potassium was significantly (P≤0.05) increased with increasing irrigation water. The greater exchangeable potassium (82.9 kg ha^{-1}) was observed on 1200 mm irrigation treatment that was 122.8% higher than no irrigated plot followed by 79.83 and 91.93% more on 600 mm and 900 mm treatments respectively. The combination of non-uniform organic matter mineralization, differences in K supply from clay minerals under different irrigation regimes and different in plant uptake rates are potential sources of difference in soil K concentration among the irrigation regimes (Djaman et al. 2013). Zeng and Brown (2000) also reported that soil K mobility increased significantly with water contents.

Water is the most limiting factor for crop production. A significant (P≤0.05) difference was observed on grain yield between irrigation water and no irrigation. The higher amount of irrigated water 1200 mm had maximum grain yield (6440 kg ha^{-1}) which were at par with treatments 600 mm (5870 kg ha^{-1}) and 900 mm (5700 kg ha^{-1}) of irrigation, but significantly different with deficit irrigation 300 mm (4960 kg ha^{-1}) and no irrigated treatment (2390 kg ha^{-1}). The grain yield on no irrigated treatment was which is 107.5, 145, 138 and 169.45% lower than 300, 600, 900 and 1200 mm irrigation application, respectively. The relative increase in maize grain yield with increasing irrigation water volumes shown in figure 1. Large amount of water in soil provides sufficient moisture for longer duration (Kumar et al. 2007) and encourages the nutrient absorption along with water (Hsiao 1990; Ismail et al. 2007). Irrigation improved air-water relationship in soil and beneficial effect of irrigation on water and nutrient availability to the crops contributed to their increased yield. Jane et al. (1989) also found similar results. However, grain yield was no significantly reduced and irrigation water was conserved by 50 % on 600 mm irrigation as

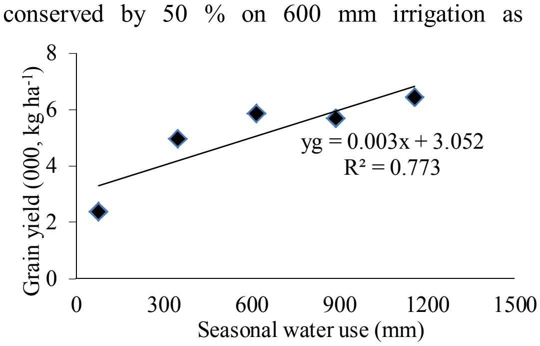

Figure 1. Relationship between seasonal water use (SWU) and maize grain yield at Chitwan, Nepal, 2012/2013

Table 4. Interaction effects of manure and irrigation applications on grain yield

Treatments	Grain yield (kg ha^{-1})		
	No manure	With manure	Average
No irrigation	2413 (777)	2363 (872)	**2390^{c}** (739)
300 mm of irrigation water	4797 (189)	5120 (279)	**4960^{b}** (277)
600 mm of irrigation water	5970 (911)	5770 (1265)	**5870^{ab}** (992)
900 mm of irrigation water	6067 (660)	5337 (295)	**5700^{ab}** (608)
1200mm of irrigation water	6247 (911)	6640 (632)	**6440^{a}** (734)
Mean	5099 (1613)	5046 (1623)	
Analysis of variances			
	P-value	LSD	SEm
Manure (M)	ns	-	0.195
Irrigation (Is)	**	920	0.308
M x Is	ns	-	0.436
CV%	14.89%		

The mean followed by the same letter(s) in a column are not significant different at 5% levels of significance. Means within a column that are not **boldface** are not significantly different. The figures in parenthesis indicate standard deviation of mean within three replications

Table 5. The effect of irrigation on maize grain yield and irrigation water use efficiency at Rampur, Chitwan, Nepal, 2012/2013

Treatments	Grain yield (kg ha^{-1})	Total gross irrigation water applied (mm)	(IWUE) based on grain yield (kg ha^{-1} mm^{-1})
No irrigation	**2390^{c}**	0 (76.7)	-
300 mm of irrigation water	**4960^{b}**	270 (346.7)	18.37
600 mm of irrigation water	**5870^{ab}**	540 (616.7)	10.87
900 mm of irrigation water	**5700^{ab}**	810 (886.7)	7.04
1200mm of irrigation water	**6440^{a}**	1080 (1156.7)	5.96

* Rainfall during growing season was 76.7 mm. The mean followed by the same letter(s) in a column are not significant different at 5% levels of significance. Means within a column that are not **boldface** are not significantly different. The value in parenthesis indicates seasonal total water use.

compare to 1200 mm of irrigation to maize crop.

In this experiment, the interaction effects of irrigation applications on above measured soil properties and crop grain yield in combination with manure application was non-significant (P>0.05) showed in table 2, 3 and 4. The reason behind in different interactions between these treatments might be due to not enough decomposition of organic manure and nutrient recycling process under different irrigation conditions. In short experiments initial 10 years, soil organic carbon is not increased significantly (Fening et al. 2011). However a result was contrasted with Aziz et al. 2010.

There was a positive correlation of seasonal water use and grain yield with R^2 value of 77.3% (Figure 1). Aghdaii and Sattar (2000) revealed a significant (direct) effect of the levels of irrigation water on maize yield ($p \leq 0.05$) and 100% irrigation level gave the maximum yield. Irrigation improved air-water relationship in soil and beneficial effect of irrigation on water and nutrient availability to crops contributed to yield (Jane et al. 1989).

The irrigation water use efficiency (IWUE) based on grain yield ranged from 5.96 to 18.37 kg ha^{-1} mm^{-1}depending on the treatments (Table 5). Even though the total yield increased with applying more water, the IWUE decreased. Considering the IWUE, the maximum values for based on grain yield of 18.37 kg ha^{-1} mm^{-1}was obtained from 300 mm irrigation application followed by 600 mm (7.04 kg ha^{-1} mm^{-1})**.** Furthermore, IWUE generally have been found to increase with decline in the irrigation quantity (Howell 2001).

CONCLUSION

Based on this experiment, organic manure with fertilizer application improved the soil nutrient contents such as soil Nitrogen and available Phosphorus than solely applied fertilizer (without manure). Long term continuous integrated use of organic manure with chemical fertilizers would be a better and practical approach to sustain soil fertility and crop productivity. Application of water improves the soil nutrient contents (SOC, P, K) as compare to non-irrigated ones except in soil Nitrogen. Grain yield was not significantly reduced on 600 mm irrigation as compare to 1200 mm of irrigation to maize crop. Based on the IWUE results, it seems that 600 mm irrigation treatments are quite suitable for the maize production in spring season with benefits of increasing IWUE and saving water around 50% of water which will help in growing more areas and in managing the limited water resources in Chitwan, Nepal.

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