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Economic Analysis of the Effect of Nitrogen and Phosphorous Fertilizer Application under Optimum Irrigation Scheduling for Potato Production at South Eastern Ethiopia

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Wise management of water, fertilizer, and soil is critical in sustainable food production. This study was conducted at Tiyo and Ziwad Dugda districts during the dry season based on the objective to analysis the economic effect of NP fertilizer application under Optimum irrigation scheduling for potato production and water productivity under irrigated condition. Two rate of NP fertilizer (recommended rate and +25% of recommended rate of fertilizer under optimum irrigation condition) and farmer's irrigation practice was used as control. The comparison of the experiment show that the maximum (20.53tons/ha) and minimum (11.85tons/ha) were obtained at +25% recommended rate and farmers practice, respectively. During field demonstration activity farmers also perceived that +25% recommended rate of fertilizer was one of the most preferred and appropriate technology for maximizing yield production, optimum irrigation water management and fertilizer rate technology. Therefore, under optimum irrigation water management practice addition of 25% fertilizer on the recommended rate gave high potato tuber yield. The economic analysis was done basis on the prevailing prices of varying treatment inputs (Urea and NPS) and outputs (Tuber Yield) during the cropping seasons using the Ethiopian currency (ETB). The economic analysis of the combined result of the experiment revealed that the profitable highest mean net return of 141,677.06 Birr/ha was obtained for the plot that received 206.25 kg/ha of Urea and 294.94kg/ha of NPS which is 38,919.41 ETB. So, this is economically optimum and profitable. Therefore, it can be concluded that application of 206.25kg of Urea and 294.94kg of NPS fertilizer per hectare in the target area is preferable to maximize profit that can be gained from Potato production under optimal irrigation condition.

Key Words: Economic Analysis, Optimal Irrigation, Potato, Fertilizer rate

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INTRODUCTION

Water is essential to grow crops, to provide food and to decrease drought risks. Irrigated agriculture globally uses more than 70% of water (Khokhar, 2017; Anonymous, 2019a). Thus, it places increasing pressure on freshwater resources, especially in developing countries. Considering demand of industrial and domestic water, the ways of efficient water use must be practiced in irrigated agriculture. Use of surface irrigation methods in the world, especially in developing countries, is still preponderant. In general, these conventional irrigation methods use water excessively. This situation is mainly dependent on the nature of these methods and farmers' conditions.

In semiarid and arid climatic conditions, increasing agricultural production is mainly dependent on irrigation. As known, the conventional irrigation methods (surface irrigation) use much more water compared to the pressurized irrigation systems such as sprinkler and drip irrigation. Increasing food demand and decreasing water resources have composed a kind of pressure to find new technologies for efficient use of water and fertilizer for agriculture. In addition, protection of soil and water resources and environmental sustainability are other crucial factors to be considered. Thus, efficient and less water and fertilizer use is significantly important in terms of environmental protection (Hagin et al., 2003).

A considerable amount of water is lost as leakage and/or evaporation during storage and transport to the fields where the crops are grown in irrigated agriculture. The runoff is also an important loss considering surface irrigation (Wallace, 2000). Thus, the most important issue on use of water resources is to minimize the amount of water used in irrigated agriculture. In order to increase water use efficiency and to shift to a more sustainable use of water in agriculture, improvement in water use efficiency is required (Barua, et al, 2018).

FAO estimates that irrigated land in developing countries will increase by 34% by 2030, but the amount of water used by agriculture will increase by only 14%, thanks to improved irrigation management and practices. Access to water for productive agricultural use remains a challenge for millions of poor smallholder farmers, especially in sub-Saharan Africa, where the total area equipped for irrigation is only 3.2% of the total cultivated area (FAO, 2011). Farmer-driven, informal irrigation is in many regions more prominent than formal irrigation. Globally, fertilizer demand is projected to continue rising. It is forecast to reach about 200 Mt towards 2020 (Heffer and Prud'homme, 2014)

Fertilizer application is one of the most effective and practical ways to control and improve yield and nutritional quality of crops for human consumption. In the current food production scenario across major cropping systems of the world, crop yield is limited more by availability of nitrogen (N) and water resources rather than by the crop genetics (T. R. Sinclair , 2012). Although the soil nutrient input on farmland is the need to make their crops grow better, soil nutrient loss from agricultural areas is a major source of pollution for freshwater and coastal ecosystems (P. C. West, 2014).

One of the key differences between researcher and farmer managed plots is that many farmers are less equipped to optimize nutrient and water use. This is essential, as both inputs are closely linked. Where current crop yields are far below their potential, improvements in soil and nutrient management can generate major gains in water use efficiency (Molden, 2007). Best management practices for improving fertilizer use efficiency include applying nutrients according to plant needs, placed correctly to maximize uptake, at an amount to optimize growth, and using the most appropriate source. These principles are reflected in nutrient stewardship programs (e.g., 4R or the "four rights", viz. right source, at the right rate, at the right time, in the right place; IFA, 2009).

Water and nutrient use within plants are closely linked. A plant with adequate nutrition can generally better withstand water stress (Gonzalez-Dugo et al., 2010; Waraich et al., 2011). For example, in rain-fed settings, farmers gain yield by applying nitrogen in conjunction with expected rainfall. Phosphorus applied at early stages of plant development can promote root growth, which is helpful in accommodating water stress. Potassium plays a key role in stomata and osmotic regulation. Plant nutrients and water are complementary inputs, and plant growth response to any nutrient or to water is a function of the availability of other inputs. Thus, the incremental return to fertilizer inputs is larger when water is not limiting, just as the incremental return to irrigation generally is larger when nutrients are not limiting. Smallholder farmers must also consider risk and uncertainty when determining whether or not to apply fertilizer, particularly in rain-fed settings. If rainfall is inadequate or late in arriving, the investment in fertilizer might generate no return. Thus, to be meaningful, the metrics used to express the performance of agricultural inputs, such as fertilizer use efficiency and water productivity, should be analyzed together, and in combination with complementary indicators reflecting the overall effectiveness of the farming system, including crop yield and soil nutrient levels. Wise management of water, fertilizer, and soil is critical in sustainable food production. use of integrated innovative crop production methods.

Materials and Methods

The study Area

The study was conducted in Ziway Dugda district, of Arsi Zone, Oromia Regional State, Ethiopia. The study area is located around 180 km from Addis Ababa capital city of Ethiopia. Geographically experimental area is located between 08˚02'19"N to 39˚00'59"E, and situated in an average altitude of 1700m above sea level.

The study area is characterized as semi-arid environment with mean monthly maximum and minimum temperature of 26.3°C and 12.3°C, respectively. The area receives an average annual rainfall of 689mm. The soil type of the experimental site is silt clay and has a field capacity of 31%, wilting point of 15 % and the total available water of 16% while; the bulk density was 1.25 g/cm.

Experimental Comparison

Potato Gudene Variety was planted on a field plot of 10mx 10m. The furrows spacing of 0.75m were used for planting potato seed on both side of a ridge at row and plant spacing of 37.50 and 30 cm, respectively. Under optimum irrigation practice recommended rate of fertilizer (235.95kg/ha NPS and 165kg/ha Urea) and addition of 25% on recommended rate were compared, when Farmers practice was used as control which is described below in Table 1.

Table 1. Combination of the Experimental Treatments

Treatment	Combinations	Fertilizer Rate (kg/ha)	
		Urea	**NPS**
T1	+25 Recommended rate of fertilizer	206.25	294.94
T2	Recommended rate of fertilizer	165.00	235.95
T3	Farmers practice (control)	150.00	195.00

All plots were irrigated with uniform amount of water few days before planting to make the soil workable. The experiment was planted 2016/17 and 2017/18 during the first week of December and January respectively. To ensure the plant establishment common irrigations was provided to all plots at two days interval before commencement of the differential irrigation. Irrigation water was applied at allowable soil moisture depletion of the total available soil moisture throughout crops growth stage. Plots were fertilized with recommended rate and +25% recommended of nitrogen and phosphorous fertilizer. Phosphorus fertilizer was applied to all plots as basal dose at planting, while the recommended rate of nitrogen fertilizer was uniformly applied in splits, half at planting and the remaining half prior to hilling.

Measured depths of irrigation water were delivered to each plot according to the treatment arrangements and irrigation schedule through a water measuring device, namely two inch parshall flume, which was installed 3 meters before the start of experimental plots.

Crop water requirement (CWR) for the optimum irrigation (100%ETc) was calculated using CropWat version 8.0 software and soil water was monitored by gravimetric method. Based on the calculated CWR, Irrigation water was applied according to the treatment percentage and the method of furrow irrigation

Soil samples before and after irrigation was taken from control treatment plots to check the moisture content before and after irrigation not to go above field capacity and below allowable moisture depletion level.

Demonstration and Farmers selection

Two districts were selected based on diversity of farmers' information obtained from Agricultural Office. Accordingly, Ziway Dugda and Tiyo districts were selected. Representative areas investigated were selected based on secondary information on agro-ecologic zone, and irrigation practice. Based on the aforementioned criteria two peasant associations were selected.

Data collection and analysis

Farmers' perception and attitudes toward the technologies were collected through group discussion and individual interview during field visit.

Potato tuber yield data was collected and water productivity was quantified by WP formula. Estimation of water productivity was carried out as a ratio of total bulb yield to the total water applied (Central Statistics, 2011).

$$\text{Water Productivity}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total Bulb Yield(kg)}}{\text{Crop Water Use (m3)}}$$

Yield profitability (Economic analysis) was calculated using the following formulas:

$$\text{Gross Return (ETB)} = \text{Total Bulb Yield (kg)} * \text{Price of Potato}\left(\frac{\text{ETB}}{\text{kg}}\right)$$

$$\text{Total Variable Cost (TVC) (ETB)} = \text{Cost of Input (ETB)}$$

$$\text{Net Return (ETB)} = \text{Gross Return(ETB)} - \text{TVC (ETB)}$$

$$\text{Marginal Rate of Return (MRR)(\%)} = \frac{\text{The difference in Net Return (ETB)}}{\text{The difference in TVC (ETB)}} * 100$$

Data Analysis

The collected data were statistically analyzed using Microsoft Excel.

Result and Discussion

The comparison of experiment showed that potato tuber yield and water productivity difference was observed between recommended rate of fertilizer and +25% recommended rate of fertilizer.

Potato tuber yield

Under optimal irrigation water management different rate of fertilizer application affected the tuber yield of potato. +25% application of fertilizer rate recorded greater tuber yield than recommended fertilizer rate. The highest tuber yield (20,525kg/ha) was recorded by treatment receiving +25% on recommended rate of fertilizer (RRF) and the lowest (14,950 kg/ha) was from recommended rate of fertilizer (Table 2).

Table 2. Applied Water, Water Productivity, Water Saved, and Yield Reduction.

Treatment	Combinations	Tuber Yield (kg/ha)	Price 1 kg (ETB)	Gross Return (ETB)
T1	+25 RRF	20,525.00	8.00	164,200.00
T2	RRF	14,950.00	8.00	119,600.00
T3	Farmers practice (control)	11,850.00	8.00	94,800.00

Yield profitability (Economic analysis)

The economic yields and added benefits as influenced by the combined use of N through urea and P through NPS fertilizers on yield of potato were calculated and presented in Table 4. Based on the principles of economic analysis using Marginal Rate of Return (MRR), the economic analysis was done on the basis of the prevailing prices of varying treatment inputs (rea and NPS) and outputs (Tuber Yield) during the cropping seasons using the Ethiopian currency (ETB). The price of NPS was 1300.00 ETB per 100 kg and urea was 1100.00 ETB per 100 kg. The prices of output at that cropping season were tuber yield of potato valued 800 Birr/100 kg. Unlike that of the physical agronomic yield, the economic analysis of the combined result of the experiment with two years and two locations revealed that the profitable highest mean net return of 141,677.06 Birr/ha was obtained for the plot that received 206.25 kg/ha of urea and 294.94kg/ha of NPS which is 38,919.41 ETB more than the net returns obtained from the recommended fertilizer rate (165 kg/ha area and 235.95kg/ha NPS) which is 102,757.65 ETB. On the other hand, the lowest net-return of 90,615.00 ETB/ha was obtained from the use of same fertilizer to the recommended rate. High net return from the foregoing treatments could be attributed due mainly to high yield and the low net return was attributed due to low yield (Table 3).

Table 3. The Combined Partial Budget Analysis (PBA) for Ziway Dugda and Tiyo districts

Trt No	Treatment	Urea (kg/ha)	NPS (kg/ha)	Gross Return (ETB)	10% price Reduction on GR (ETB)	TVC (ETB/ha)	Net Return (ETB/ha)	DA	MRR (%)
T1	+25 RRF	206.25	294.94	164,200.00	147,780.00	6,102.94	141,677.06	*	3189
T2	RRF	165	235.95	119,600.00	107,640.00	4,882.35	102,757.65	D	-
T3	Farmers Practice	150	195.00	94,800.00	85,320.00	4,185.00	90,615.00	-	-

Note: TVC=Total Variable Cost, GR= Gross Return, ETB= Ethiopian Birr, DA= Domino A--, D= Domino,

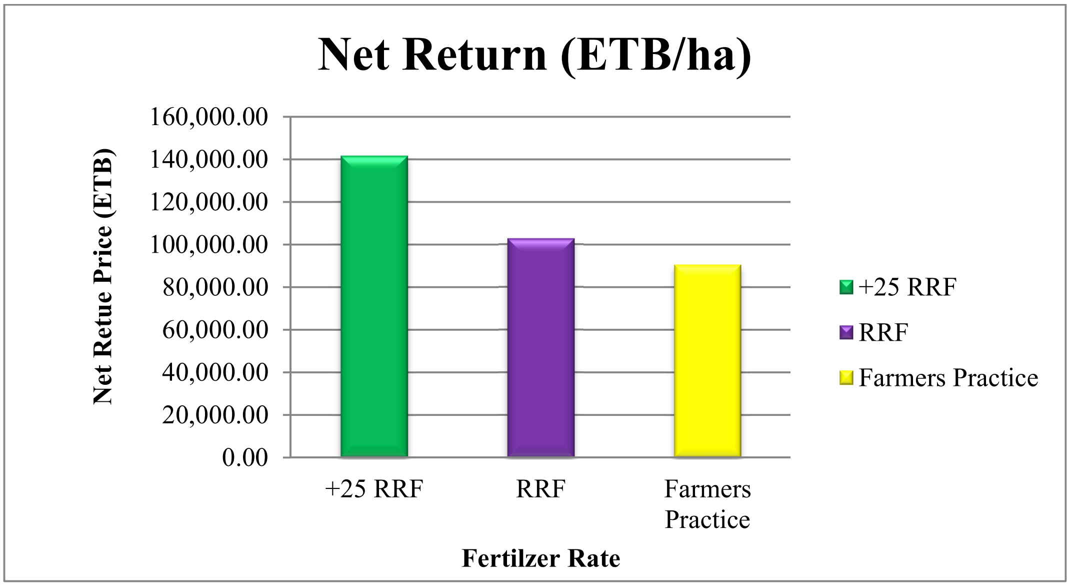

Figure 1. Comparison of fertilizer rate

Conclusion and Recommendation

Two districts were selected based on diversity of farmers' information obtained from Agricultural Office. Accordingly, Ziway Dugda and Tiyo districts were selected. Representative areas investigated were selected based on secondary information on agro-ecologic zone, and irrigation practice. Based on the aforementioned criteria Arata Chufa and Gonde peasant associations were selected from each districts, respectively.

During field visit and demonstration farmers also perceived that +25 recommended rate of fertilizer was one of the most preferred and appropriate technology for maximizing yield production and participant farmers gave their evidence during field visit about optimum irrigation water management and fertilizer rate technology. Therefore, under optimum irrigation water management practice addition of 25% fertilizer on the recommended rate gave high economic return.

A field experiment was conducted on silty clay soils of Tiyo and Ziway Dugda district, Arsi Zone, Ethiopia for two consecutive years with the aim of determining the optimal fertilizer application rate and the most profitable level for potato production under optimal irrigation. Two rate of NP fertilizer (recommended rate and +25% of recommended rate of fertilizer under optimum irrigation condition) and farmer's irrigation practice was used as control. The comparison of the experiment show that the maximum (20.53tons/ha) and minimum (11.85tons/ha) were obtained at +25% recommended rate and farmers practice, respectively. During field demonstration activity farmers also perceived that +25% recommended rate of fertilizer was one of the most preferred and appropriate technology for maximizing yield production, optimum irrigation water management and fertilizer rate technology.

Therefore, under optimum irrigation water management practice addition of 25% fertilizer on the recommended rate gave high potato tuber yield. The economic analysis was done basis on the prevailing prices of varying treatment inputs (Urea and NPS) and outputs (Tuber Yield) during the cropping seasons using the Ethiopian currency (ETB). The economic analysis of the combined result of the experiment revealed that the profitable highest mean net return of 141,677.06 Birr/ha was obtained for the plot that received 206.25 kg/ha of Urea and 294.94kg/ha of NPS which is 38,919.41 ETB more than the net returns obtained from the Recommended fertilizer rate (165 kg/ha Urea and 235.95kg/ha NPS) which is 102,757.65 ETB. According to economic analysis result, this level of nitrogen and phosphorous fertilizer application is the level at which the highest gross margin and net return. So, this is economically optimum and profitable. Therefore, it can be concluded that application of 206.25kg of Urea and 294.94kg of NPS fertilizer per hectare in the target area is preferable to maximize profit that can be gained from Potato production under optimal irrigation condition.

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