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Effect of split nitrogen application and fertilizer rate on yield of Irish potatoes (Solanum tuberosum) in a smallholder farming sector of Zimbabwe

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Abstract

An experiment was carried out to determine the effects of split nitrogen application and different nitrogen fertilizer rates on the productivity of Irish potatoes (*Solanum tuberosum L*) in smallholder farming in Zimbabwe. The experiment was laid out in a randomized complete block design with three nitrogen application levels (15g m^{-2}, 30g m^{-2} and 45g m^{-}2) and three split application levels (1, 2 and 3), and was replicated three times. The results of the study showed that nitrogen rate had a significant effect ($p<0.05$) on number of tubers, tuber size and on the final yield of the potato. The highest yield was obtained in a at 30g N m^{-2} with the 15g N m^{-2} producing the least. Split application had a significant effect ($p<0.05$) on number of potato tubers, size of potato tubers as well as the overall yield of the potatoes. From the study findings, it can be concluded that three (3) split applications applied at 30g m^{-2} had the potential to increase the yield compared to the other treatments. Farmers are therefore urged to apply top dressing nitrogenous fertilizer in three treatments to ensure a higher productivity of Irish potatoes.

1. Introduction

Irish potatoes are becoming an important component of the diet for both rural and urban households in Zimbabwe. The integration of Irish potatoes in diets could be a rational coping strategy by households to ensure food security. Potatoes provide adequate amounts of energy (Sithole, 2007), and the production of the crop helps in the creation of employment for people in the smallholder farming sector (Johnson, 2010).

The potato crop yield can be up to 60 t ha^{-1} in commercial farms and ranges between 15-24 t ha^{-1} in smallholder farming (ZCFU, 2012). There are various factors that contribute to the low yields of potatoes in the rural areas. Poor soil fertility is one of the principal factors hampering potato production in Zimbabwe (Hutchinson, 2005). Nutrient chemical fertilizers, especially nitrogen and phosphorus, are required to correct the nutrient imbalance in infertile soils (Grawal *et al*, 2001). Nitrogen influences vegetative growth and the uptake of other nutrients such as potassium and phosphorus (Khurma *et al*, 2009; Jamaati *et al*, 2010).

Since nitrogen is highly mobile, its use and demand is continuously increasing as it is subjected to high loss from the soil plant system (Randal, 2000). Even under best management practices, approximately 30-50% of applied nitrogen is lost through different agencies and, hence, the farmer is compelled to apply more than what the crop needs to compensate for losses through leaching, volatilization, and denitrification making the nutrient unavailable during the critical stages of crop growth (Pack, 2004; Hyatt *et al*, 2010).

Many strategies have been developed to mitigate nutrient leaching and improve nutrient use efficiency. Timing of fertilizer application and manipulation of fertilizer rates are low cost strategies for reducing nutrient leaching so that nutrient supply is synchronized with plant nutrient demand (Worthington *et al*, 2007). Split application of nitrogen is one of the strategies of improving nitrogen use by the crops (Sithole, 2007). Jaamati *et al*, 2010 reported overall improvement in yield as an additional advantage of splitting nitrogen, while Hutchinson *et al*, 2003 cited the environmental protection advantage of the practice. By postponing a portion of the nitrogen application until the crop is better able to utilize the nutrient, plants quickly and efficiently take up more nitrogen and resulting in farmers getting more returns from the dollar invested on fertilizer.

This research seeks to determine the effect of splitting varying levels nitrogen on the yield of potatoes. It is hypothesized in this research that splitting N fertiliser application increases fertiliser use by the crop, and increases tuber size, number and final yield.

2. Method

The experiment was carried out in Hurungwe district of Mashonaland west province of Zimbabwe. The site is located 105 km west of Karoi and it falls under Natural Region 2a of Zimbabwe. The region receives average annual rainfall of 850 mm per annum, and has temperature ranging between 21-28ºC (Vincent and Thomas, 1965). The area is characterized by flat well drained sandy-loam soils and the Savanna type woodlands and the altitude of the area is about 1200 m (TRB, 2012).

A Randomized Complete Block Design was used, with three (3) fertiliser application (15 g/ plant, 30 g/ plant and 45 g/ plant) as the main factor, and three (3) split application levels (1, 2, 3) as the sub-factor (Table 1). The fertiliser treatments were applied by hand.

Table 1: N-fertiliser rate and split application frequency treatments

Treatment	Fertilizer amount and splits applied	Description
1	15 g ×1 application	15 g was only applied at blooming period
2	15 g × 2 applications	7.5 g fertilizer application 30 days after planting and the other 7.5 g at the first sight of bloom period
3	15 g × 3 applications	5 g of fertilizer applied at planting, 5 g at 30 days after planting and the last 5 g at the first sight of the bloom period
4	30 g × 1 application	30 g was applied at the first of bloom period
5	30 g × 2 applications	15g fertilizer application 30 days after planting and the other 15 g at the first sight of bloom period
6	30 g × 3 applications	10 g of fertilizer applied at planting, 10g at 30 days after planting and the last 10g at the first sight of the bloom period
7	45 g × 1 application	45 g was applied at the first of bloom period

8	45 g × 2 applications	22.5g fertilizer application 30 days after planting and the other 22.5 g at the first sight of bloom period
9	45 g × 3 applications	15 g of fertilizer applied at planting, 15 g at 30 days after planting and the last 15 g at the first sight of the bloom period
10	No control	No fertilizer was applied in the control treatment

Ploughing and land preparations were done according to the normal farmer practice (ZFU, 2010). Disease free potato planting seeds were planted in ridges 10 cm deep on an area of 2 m × 0.9 m per plot and about three seedlings emerged per seed. A pre-mergence herbicide (Alachlor) was applied just after planting to hinder sprouting of weeds. An insecticide (Acephate and Lambda) were used to control cutworms and termites as well as the nematicide (Nemacur) was applied to control nematodes in the field.

Basal dressing of 80 g/ m^2 of compound S was applied in furrows to encourage good leaf and stem formation. Ammonium Nitrate (34.5 % N) was applied as a top dressing was applied as prescribed in table 1.

Watering was done and the soils were kept constantly wet to a depth of at least 10-15cm. During humid or favourable weather conditions irrigation was done every two days while during unfavorable (dry) conditions, the plants were watered every day to maintain constant moisture. Ten plants were randomly selected from each treatment and during harvesting, number of tubers per plant was counted and tuber circumference (cm) was measured using a ruler. Data on tuber circumference, tuber number and yield was analyzed using Genstat 9.2 Edition (2007).

3. Results

Table 2: Effect of application of N application rate and split application levels on potato tuber circumference

Split application levels	Fertiliser level		
	15	30	45
1	20.0[a]	18.9a	13.7[a]
2	21.3[b]	21.7b	21.7[b]
3	22.0[b]	22.6b	22.6[b]
LSD $_{0.05}$	0.8	2.3	1.0
P value	0.02	0.02	0.00

There were significant ($p < 0.05$) tuber circumference differences due to splitting of N fertiliser applications at 15 g/ N fertiliser/ plant rate. The tuber circumference for the potatoes that were harvested from a plot where N fertiliser was split twice was smaller ($p< 0.05$) than that for the plot where fertiliser was applied once. The plot where splitting of N fertiliser was done three time had the highest tuber circumference. The same trend was observed at 30g/ plant and 45 g/ plant N fertiliser rate treatments. There was a strong interaction ($p < 0.05$) between fertiliser application rate and N fertiliser splitting levels on potato tuber circumference.

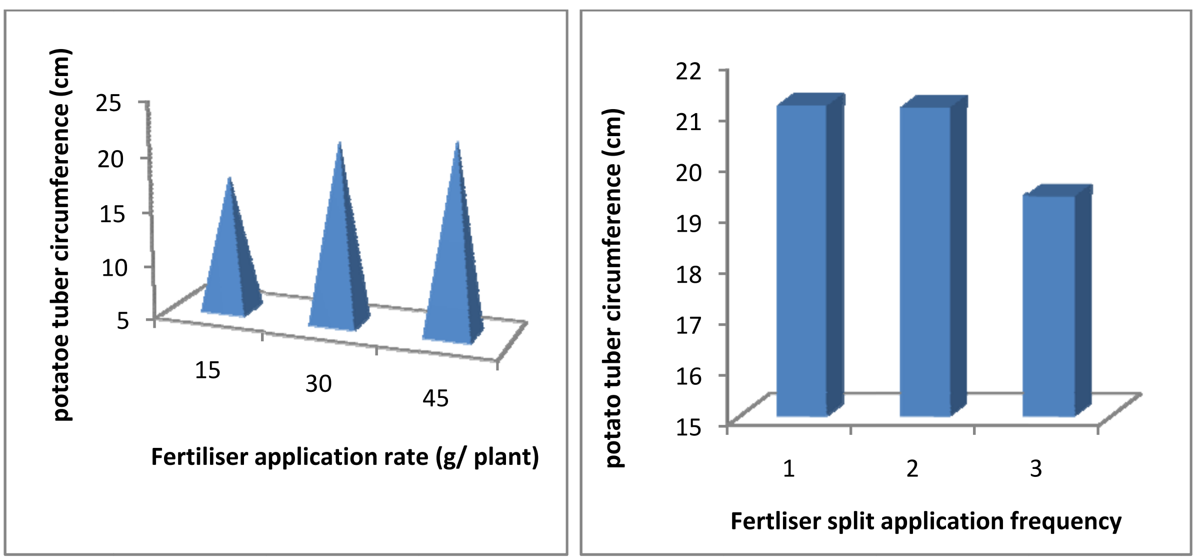

Figure 1: Effect of (a) fertiliser application rate and (b) fertiliser split application frequency on potato tuber circumference.

Generally, the potato tuber circumference increased as the split application rate increased (Figure 1 a). The potato tuber circumference for plots where N fertiliser was applied all at once and those where N fertiliser was split twice were statistically similar ($p > 0.05$) and the two were significantly ($p < 0.05$) greater than those from the plots where N fertiliser was split three times (Figure 1 b). tuber circumference the fertiliser application rate increased (figure 1a). Generally, as the N fertiliser application split application frequency there was a decrease in the potato tuber circumference increased (figure 1 b).

Table 3: Effect of application of N application rate and split application levels on the number of potato tubers/ plant

Split applications	**Fertiliser level**		
	15	**30**	**45**
1	48.0[b]	29.3b	32.0[b]
2	42.0[a]	28.0a	32.0[b]
3	41.3[a]	26.7a	30.7[a]
LSD $_{0.05}$	4.3	1.5	0.9
P value	0.01	0.03	0.02

NB: Means followed by the same letter within the column are not significantly different at P<0.05

There were significant differences ($p < 0.05$) in the tuber counts/ plant due to splitting of N fertiliser applications at 15 g/ N fertiliser/ plant rate. The potato tuber count/ plant for the plot where N fertiliser was applied once (48) was larger ($p < 0.05$) than those for the plots where fertiliser was split twice (42) and thrice (41.3). Generally, the potato tuber count/ plant decreased both as the split application levels increase from 1 to 3 (Figure 2a), and as the fertiliser application rate increases from 15 g/ plant to 45 g/ plant (Figure 2b).

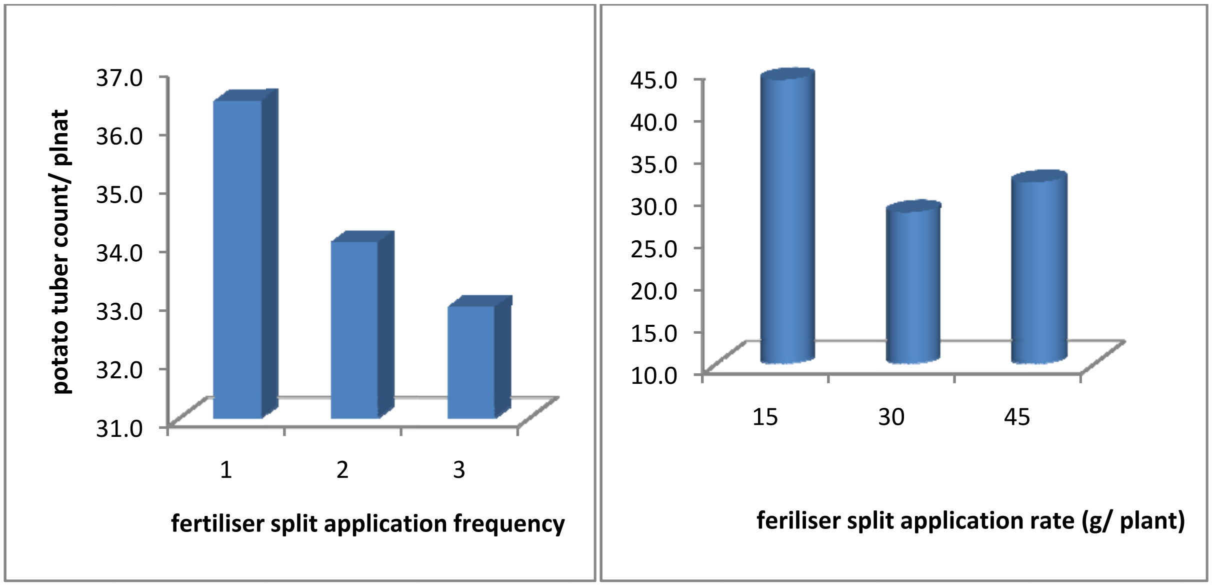

Figure 2: Effect of (a) fertiliser application rate and (b) fertiliser split application frequency on potato tuber count/ plant.

Table 3: Effect of application of N application rate and split application levels on potato yield (t/ ha)

Split applications	**Fertiliser level**		
	15	**30**	**45**
1	20.0[a]	37.6a	31.7[a]
2	21.3[a]	39.1b	33.1[b]
3	22.0[b]	39.8b	33.4[b]
LSD $_{0.05}$	1.3	1.2	1.1
P value	0.02	0.00	0.01

NB: Means followed by the same letter within the column are not significantly different at P<0.05

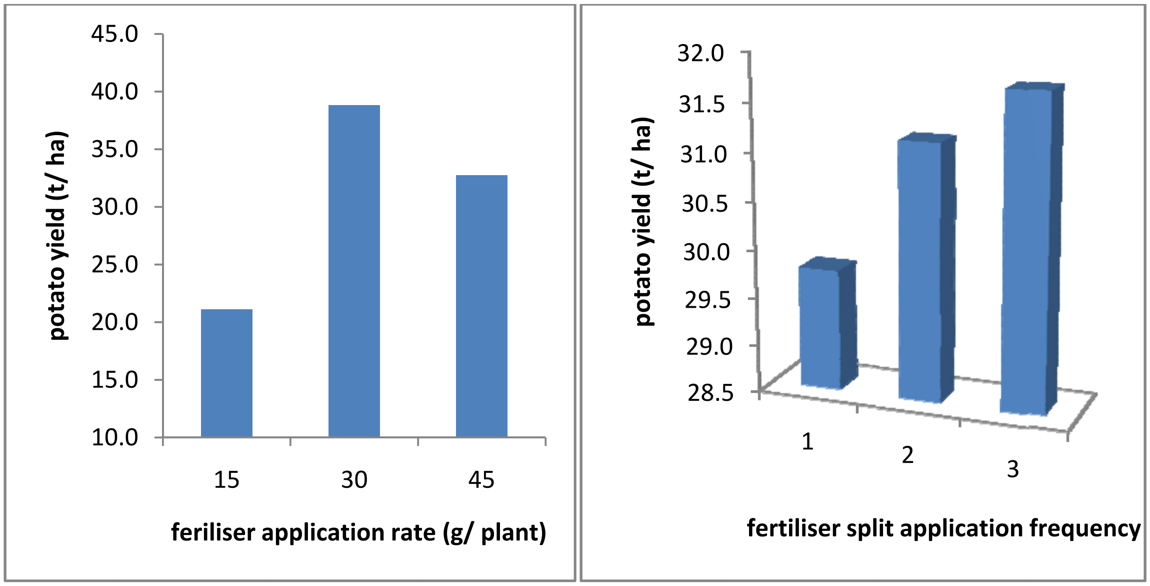

Figure 3: Effect of (a) fertiliser application rate and (b) fertiliser split application frequency on potato yield (t/ ha).

Generally, the potato yield increased both as the split application levels increase from 1 to 3 (Figure 3a), and as the fertiliser application rate increases from 15 g/ plant to 45 g/ plant (Figure 3b). Potato yield differences at significant differences due to split fertiliser application frequency at 15 g N application rate/ plant were significant ($p < 0.05$). The potato yield was the lowest where N fertiliser was the least (20 t/ ha). The highest yield (38.8 t/ ha) was attained when fertiliser was applied at 30g/ ha. The yield for the highest fertiliser application rate treatment (45g/ ha) was 32.7 t/ ha). Potato yield was the highest (31.7 t/ ha) at fertiliser application was split 3 times. The potato yield 29.8t/ ha and 31.2 t/ ha when fertiliser application was split once and twice respectively.

4. Discussion

The decrease in potato tuber circumference and tuber mass as the frequency of splitting N fertiliser increased could be an indication of the need for proper N management in potato production. Although the N supply early in the season can be adequate for vegetative growth, high levels of soil N before or at tuberization can delay tuber initiation, reduce yields and decrease specific gravity (Davis *et al*, 2014). In addition, excessive N in late summer and early fall can delay maturity of the tubers and result in poor skin set, which can adversely affect tuber quality and storage characteristics.

A once off application of 15, 30 and 45g of nitrogen fertilizer produced small tubers because most of the nitrogen may have been lost due to de-nitrification, leaching and volatilization and therefore making them unavailable during the critical stages of plant growth (Jamaati *et al*, 2010). Portier *et al*, 2007 indicated that applying total nitrogen once increases nitrogen losses through leaching and hence producing small tubers. The high mobility of nitrogenous fertilizers means that it is subjected to high losses from the plant system (Worthington *et al*, 2007; Hyatt *et al*, 2010).

The increase in the potato tuber circumference as the rate of N fertiliser application increased and the decrease in tuber count/ plant as both the rate of fertiliser application and the fertiliser split application frequency increased supported the earlier findings by Portier *et al* (2007). Excessive nitrogen application promotes excessive vegetative growth at the expense of reproduction that subsequently has a negative effect on tuber formation (Hiller *et al*, 2008). Growth parameters like plant height, number of leaves per plant, number of shoot per plant, fresh and dry weight of shoot per plant increased with an increase in nitrogen levels (Banjare *et al*, 2014).

The increase in potato tuber yield/ ha as both the fertiliser application rate and the fertiliser split application frequency increased was explained by Banjare *et al*, (2014) who noted the increase in yield attributing parameters like number of stolon, fresh and dry weight of tuber per plant increased with an increase in nitrogen levels. The results was an overall increase in the average fresh tuber weight, tuber N and NO3-N concentrations, and decreased specific gravity as nitrogen fertilization increased.

The importance of splitting N applications was also emphasized by Jaamati *et al* (2010) who showed that dividing total nitrogen into two or more applications would assist in enhancing the nutrient efficiency, promote optimum yield and mitigate the loss of nutrients and hence bigger potatoes. High nutrient availability early in the growing season does not influence tuber initiation

(Lang et al., 1999). Nitrogen applications which are split between pre-plant and in-season provide opportunities to increase nitrogen use efficiency and minimize leaching by preventing excess availability.

Kunkel *et al*., (1977) also reported the elevation of salt levels in the soil and the adverse influence on moisture availability in the zone of new root growth, as the effects of excessive amounts of nitrogen at planting. Similarly other proponents of split application emphasized the need to avoid excess nitrogen availability during growth stages I and II as a way of enhancing a balanced proportion of roots and shoots, resulting in enhanced tuber set (Lang et al., 1999; Kleinkopf and Ohms, 1977). Maximizing early tuber initiation and set increases the potential duration of tuber bulking phase of development.

5. Conclusion

Potato tuber circumference decreased as the frequency of increased, while an increase is noted as the rate of fertiliser application is increased from 15 – 45 g/ plant. Potato tuber count/ plant decrease both as the splitting frequency and the rate of N application increased. As both the N fertiliser application rate and the split application frequency increased, potato tuber yield/ ha increased. An application rate of 30 g/ plant and a split application frequency of three could be adopted by growers in the project areas and in similar environments as described for the project, as optimal for high potato yield/ ha

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