American Journal of

Plant Nutrition and Fertilization Technology

ISSN 1793-9445

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS American Journal of Plant Nutrition and Fertilization Technology

ISSN 1793-9445
DOI: 10.3923/ajpnft.2016.15.20

Research Article
Effect of Nitrogen and Irrigation on Potato Varieties in West Ethiopia

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Abstract

Objective: Ethiopia has possibly enormous potential for potato production. The average national yield is less compared to other countries due to lack of optimum fertilization and irrigation. To improve these agronomic practices an experiment was conducted in Jimma University College of Agriculture and Veterinary Medicine greenhouse to compare the effect of nitrogen rates and irrigation regimes on yield and yield component. **Methodology:** The experiment was 3×3×3 factorial with three replications laid down in a randomized complete block design comprising Jalene, Guassa and Degemeng potato varieties: 130, 110 and 90 kg ha^{-1} nitrogen rates and 100, 80 and 60% irrigation regimes. Data was subjected to analysis of SAS 9.2 software and means separation were made using Least Significant Difference (LSD) at 5% significance level. **Result:** The results indicated effects of variety and irrigation significantly affected stem number and LAI. Both irrigation and variety highly significantly affected total dry weight and tuber number. Degemeng variety recorded the highest dry weight, followed by Jalenie and Guassa. The highest total dry weight was obtained at 100% irrigation, while 60% irrigation produced the lowest. Variety and irrigation interaction significantly affected tuber fresh weight. Guassa variety at 100% irrigation recorded the highest tuber fresh weight. Degemeng variety at 60% irrigation recorded the lowest tuber fresh weight. **Conclusion:** From the results, it can be concluded that irrigation regimes and variety were significantly affected yield and yield components while the nitrogen rates were not influenced yield and yield components of the potato varieties significantly. Further research involving higher nitrogen rates and same irrigation regimes followed by post harvest activity and quality considerations in greenhouse and open field is suggested.

Key words: Jalenie, Guassa and Degemegn varieties, nitrogen rates, irrigation regimes

Received: December 09, 2015 Accepted: May 09, 2016 Published: September 15, 2016

Citation: Egata Shunka Tolessa, Derbew Belew, Adugna Debela and Beshir Kedi, 2016. Effect of nitrogen and irrigation on potato varieties in West Ethiopia. Am. J. Plant Nutr. Fert. Technol., 6: 15-20.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato (*Solanum tuberosum* L.) ranks 4th after wheat, rice and corn in production volume[1]. But it is first from root and tuber crops followed by cassava, sweet potato and yam[2]. Potato has got production potential of about 327 million tons and 18.6 million hectares worldwide[3]. Potato was introduced to Ethiopia[4] in 1858. Since then, farmers in Ethiopian high lands began cultivating the potato tuber as compensation in case of other crops failure. In Ethiopia, the estimated land under potato cultivation each year[5] is over 160,000 ha.

Though potato has been under cultivation for 154 years in the country, its production was not widely spread and it contributed little to food security in the country. The national average yield[6] is approximately 7.9 t ha^{-1}. Which is very low compared to the world[2] average of 16.4 t ha^{-1}. Among reason associated to this, lack of optimum fertilization and less use of irrigation water get emphasis now a days. To improve these agronomic practices, research was conducted to quantify and compare the effect of nitrogen rates and irrigation regimes on yield and yield component of Jalenie, Guassa and Degemegn potato varieties.

MATERIALS AND METHODS

The experiment was conducted in Jimma University, College of Agriculture and Veterinary Medicine greenhouse. The experiment was 3^3 factorial combination with three replications laid down in randomized complete block design. The factors were nitrogen in three rates (130 kg ha^{-1} = 2.93 g per pot, 110 kg ha^{-1} = 2.48 g per pot, 90 kg ha^{-1} = 2.03 g per pot), irrigation in three regimes (full irrigation = 100, 80 and 60% of full irrigation) and three varieties (Jalenie, Guassa and Degemegn). The soil medium used for growing the potato varieties was prepared from uniform soil characteristics and 12 kg in weight filled to pots of 15 L. The texture of the soil was clay with 8.7 pH, 0.86 g cm^{-3} bulk density, 0.5 EC dS m^{-1} as well as 4.3, 7.5 and 0.192% organic carbon, organic matter and nitrogen content, respectively (Table 1). The field capacity and permanent wilting point were 37.82 and 23.11%, respectively while the water holding capacity of the soil was 147.1 mm m^{-1}.

Before planting sprouted tuber of similar size at 10 cm depth, the irrigation scheduling was done using two installed tensiometer at 12 and 24 cm depth of the growing media to control irrigation frequency after calculating readily available soil water or irrigation water amount (Table 2). The soil water potential obtained from each tensiometer at each depth in cent bar in growth periods was presented in Fig. 1. Figure 1 represented the irrigation management was carried out between 20 and 50 cent bars[7]. But after April 13 near flowering and tuberization stage the crop wilts even though the tensiometer readings were not reached (Table 3, Fig. 1). Due to this reason, watering was done before adjusted tensiometer reading was achieved. Effective rooting depth used were 30 and 60 cm (Table 2) was obtained from[8] together with P (irrigation depletion fraction or maximum allowable depletion). The total available soil water (TAW) were 44.13 and 88.26 mm (Table 2). Watering was done manually using watering cane. The depletion factors for growing periods and irrigation regimes were presented in Table 4. The irrigation was performed at irrigation criteria of 20-25 cent bars for 25% available soil water depletion from planting day up to 55 days after planting, 30-35 cent bars for 30% available soil water depletion was from 56-90 days after planting and 44-50 cent bars for 50% available soil water depletion beyond 90 (Table 3-5). The last irrigation was with held 10 days before harvest to allow the tubers to harden their skin before harvesting.

The fertilizers used were urea ($CO[NH_2]_2$) (46% N) and 90 kg ha^{-1} of DAP (46% P_2O_5). The amount of fertilizers used in this study was applied based on soil test using band method. Half of the nitrogen fertilizers and entire phosphorus

Table 1: Physical and chemical properties of the soil

Soil	Exchangeable basis C mol (+) kg^{-1} soil					Micronutrients (ppm)				Field capacity (%)	Permanent wilting point (%)	Bulk density	pH1:25	Ec (dS m^{-1})	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	C:N ratio	Available phosphoreus (ppm)
	Na	K	Ca	Mg	Meq/100 g	Cu	Fe	Mn	Zn										
Clay	24.0	2.9	25.4	4.0	32.4	0.1	14.4	1.3	1.9	37.82	23.1	0.86	8.7	0.5	4.3	7.5	0.6	7.7	29.0

Table 2: Irrigation schedules throughout growth periods

No. of days after planting	Depth (m)	Total available water (mm m^{-1})	Depletion factor	No. of days irrigated	100% irrigation water (mL)	80% irrigation water (mL)	60% irrigation water (mL)
1-25	0.3	44.13	0.25	10	441	353	265
30	0.3	44.13	0.25	20	441	353	265
45	0.3	44.13	0.3	15	531	425	319
12	0.6	88.26	0.5	4	1768	1414	1061

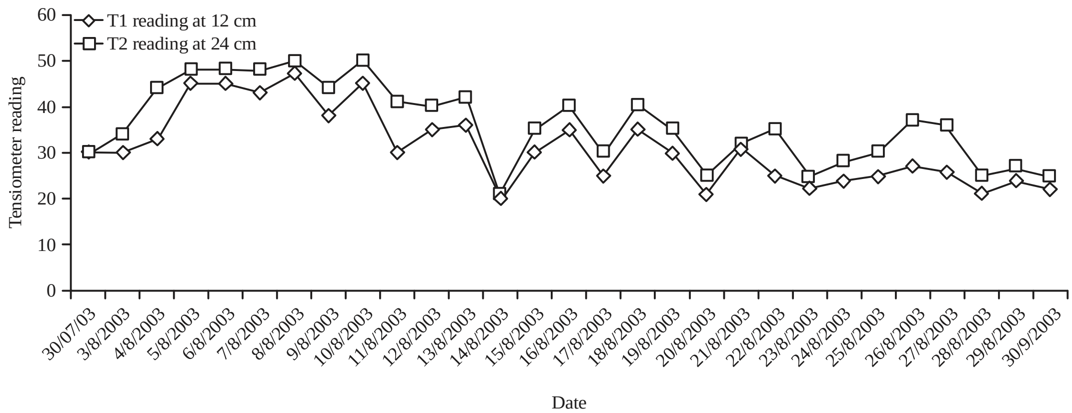

Fig. 1: Tensiometer reading for days of the growing periods in cent bars

Table 3: Irrigation water amount for growth periods and irrigation levels

Irrigation periods	No. of days	100% irrigation (mL)	80% irrigation (mL)	60% irrigation (mL)
January,16-Feburary, 11	25	441	353	265
February, 12-March, 12	30	441	353	265
March, 13-April, 28	45	531	425	325
April, 29-May, 11	12	1768	1414	1061

Table 4: Irrigation depletion factor for the three irrigation levels

	Depletion factor (%)		
Days after planting	100	80	60
1-55	0.25	0.20	0.15
56-90	0.30	0.24	0.18
90-120	0.50	0.40	0.30

Table 5: Weight of soil media, tensiometers reading and weight loss

Date in G.c	Weight measured (kg)	Tensiometer reading (cent bars)	Weight loss (kg)
17/01/03	14.84	15	-
20/01/03	14.62	17	0.22
23/01/03	14.27	20-25	0.441
26/01/03	14.15	30-35	0.531
29/01/03	12.96	44-50	1.768

requirement was applied as basal while the remaining amount was applied at 45 days after planting[9]. The amount of phosphorus requirement was 90 kg ha^{-1}. All of the other cultural practices used throughout the growing season were similar to those that were practiced by regular farmers. Tuber harvesting was done once at proper physiological maturity (70% leaves withering). Tuber and shoot samples had undergone an oven drying at 65°C until constant weight was reached. Data was subjected to analysis of variance using proc General Linear Model (GLM) procedure of SAS 9.2 software[10]. The means were compared with Least Significant Difference (LSD) at 5% significance level.

RESULTS AND DISCUSSION

Number of stem per pot: Number of stems per pot was significantly influenced by effects of variety and irrigation. The interactions between and among factors and nitrogen rates did not affect stem number per pot significantly (Table 6). Stem number per pot of Jalenie and Guassa varieties were not significantly different. Highest stem number per pot was registered from Jalenie and Guassa varieties while the lowest was obtained from Degemegn. Significantly, high stem number (8.15) (Table 6) was obtained at 100% irrigation but was not statistically different from that obtained at 80% irrigation. The least number of stems per hill (6.85) was recorded at 60% irrigation (Table 6).

Leaf Area Index (LAI): The leaf area index was significantly affected by variety and irrigation (Table 6). The maximum leaf area index was obtained from Guassa and Jalenie varieties while the minimum LAI was obtained from Degemegn variety. The effect of nitrogen rates and interaction on the LAI was not significant. Significantly, the highest LAI was obtained at 80 and 100% irrigation. The least LAI was observed at 60% irrigation.

Dry weight: Effects of irrigation and variety highly significantly affected total dry weight (Table 6). Significantly the lowest total dry weight was recorded by Degemegn variety, followed by Guassa and Jalenie. However, there was no significant difference among the latter two varieties. Significantly, the highest total dry weight was obtained at 100% irrigation even though statistically similar with 80% irrigation, while 60% irrigation produced the lowest. Decreasing irrigation water by

Table 6: Influence of nitrogen rates and irrigation regimes on varieties vegetative and tuber yield parameter

Treatment	Stem number	LAI	Tuber to shoot ratio	Shoot dry weight (g)	Tuber dry weight (g)	Total plant dry weight (g)	No. of tuber	Tuber fresh weight (g)
Variety								
Jalene	8.4681^{a**}	4.1994^{a*}	1.6684^{a**}	32.333^{b**}	42.007^{a**}	75.185^{a**}	21.741^{a**}	245.51^{a**}
Guassa	7.9507^{a**}	4.3126^{a*}	1.5328^{a**}	31.683^{b**}	36.372^{a**}	68.055^{b**}	21.148^{a**}	216.4^{a**}
Degemegn	6.4078^{b**}	3.4594^{b*}	0.6921^{b**}	38.789^{a**}	24.63^{b**}	63.423^{b**}	10.407^{b**}	81.18^{b**}
Nitrogen (kg ha^{-1})								
130	7.8030^{ns}	4.0562^{ns}	1.2612^{ns}	34.439^{ns}	34.784^{ns}	69.223^{ns}	18.037^{ns}	170.33^{ns}
110	7.8637^{ns}	4.1939^{ns}	1.3435^{ns}	33.574^{ns}	35.208^{ns}	68.782^{ns}	18.667^{ns}	195.03^{ns}
90	7.1600^{ns}	3.7213^{ns}	1.2886^{ns}	34.792^{ns}	33.865^{ns}	68.658 ^{ns}	16.593^{ns}	177.91^{ns}
Irrigation (%)								
100	8.1493^{a*}	4.1581^{a*}	1.6242^{a**}	37.662^{a**}	41.458^{a**}	79.120^{a**}	21.037^{a**}	253.25^{a**}
80	7.8259^{ab*}	4.3047^{a*}	1.4538^{a**}	34.294^{b**}	38.799^{a**}	73.093^{a**}	18.481^{a**}	195.81^{a**}
60	6.851^{b*}	3.5086^{b*}	0.8153^{b**}	30.849^{c**}	23.600^{b**}	54.450^{b**}	13.778^{b**}	94.21^{b**}
LSD	0.9757	0.5001	0.5532	2.8239	6.5495	6.8916	3.9787	59.317
CV% at $\alpha = 5\%$	13.127	16.981	16.363	4.434346	17.86053	13.50192	12.24522	14.25899

*Means of the same factor followed by the same letter with in the column are not significantly different at 5% level of probability, **Means of the same factor followed by the same letter with in the column are not significantly different at 1% level of probability, LSD: Least significant difference, CV%: Coefficient of variance and ns: Non significantly difference at 5% level of probability

40% resulted in 18.1% reduction in total dry weight. Nitrogen and interaction between or among the factors did not affect tuber dry weight. Tuber dry matter was highly significantly (p<0.01) affected by variety and irrigation (Table 6). But it was not significantly affected by nitrogen and interaction among the different factors. The maximum tuber dry weight was obtained from Jalenie and Guassa varieties while the minimum was obtained from Degemegn variety. Significantly, the highest tuber dry weight was obtained at 100% irrigation even though statistically similar with 80% irrigation, while 60% irrigation produced the lowest.

Average tuber number and fresh weight: Effects of irrigation and variety highly significantly (p<0.01) affected the tuber numbers per plant (Table 6). Significantly, the highest number of tubers per plant was recorded by Jalenie followed by Guassa variety. However, there was no significant difference between these two varieties. Nitrogen and interaction levels between or among the factors did not affect average tuber number (Table 6). Statistically similar highest tuber numbers were obtained from 80 and 100% irrigation while the lowest tuber number was recorded by 60% irrigation. Interaction between variety and irrigation significantly affected tuber fresh weight (Fig. 2). As shown in Fig. 2, Guassa variety at 100% irrigation recorded significantly the highest tuber fresh weight. However, it was not significantly different from that obtained from Jalenie variety at 100 and 80% irrigations. The lowest tuber fresh weight was recorded from Degemegn variety at all irrigation regimes as well as, Jalenie and Guassa varieties at 60% irrigation. Decreasing the irrigation water by 40% for Jalenie caused reduction of 64.4% tuber weight while

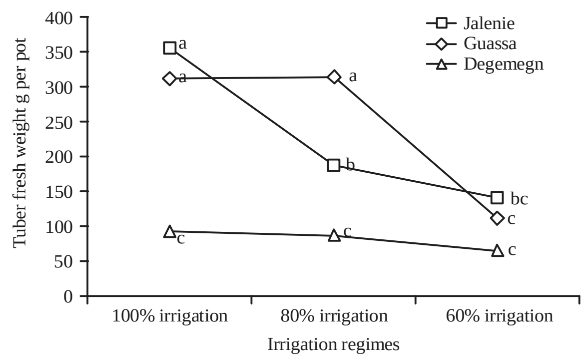

Fig. 2: Interaction effects of variety and irrigation on average fresh tuber weight (g), a: Highly significantly the highest tuber fresh weight in gram per pot, b, bc: Highly significantly medium yield and c: Lowest tuber fresh weight gram per pot. Line with triangles represented tuber fresh weight in gram per pot obtained from Degemegn variety at each irrigation regimes, line with rectangle represented tuber fresh weight in gram per pot obtained from Guassa variety at each irrigation regimes. Line with rectangle and represented tuber fresh weight in gram per pot obtained from Jalene variety at each irrigation regimes

decreasing the irrigation water by 20 and 40% reduced the tuber yield of Guassa by 47.3 and 60.3%, respectively.

The results of average stem number per pot (8.4681 for Jalenie, 7.9507 for Guassa and 6.4078 for Degemegn) were different for different varieties which agreed with findings of Zelalem *et al.*[9] in which stem density was influenced by potato varieties but not affected by nitrogen rates. Different authors reported dependence of stem number on very early ontogeny of plant[11,12]. As indicated in Allen[13] number of stems was strongly influenced by storage condition of tubers, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions. The numbers of stems per pot were affected by irrigation regimes. It showed increasing trend with increasing water supply to field capacity. Leaf Area Index (LAI) results of potato varieties of the present investigation (4.1994, 4.3126 and 3.4594 for Jalene, Guassa and Degemegn, respectively) were slightly higher than those reported by Pereira *et al.*[14] for different varieties of potato. This could probably be due to difference in area coverage used for calculating the leaf area index and other conditions such as environmental and crop factors. Higher leaf area index results in more land coverage and light interception which in turn results in higher photosynthesis and yield[15]. The LAI results at different irrigation regimes (4.1581, 4.3047 and 3.5086 for 100, 80 and 60%), respectively were smaller than the autumn maximum leaf area index of non-stressed and stressed treatments[16] while, it was higher than spring unstressed treatments. This difference is attributed to variation in climate, variety and season of production. LAI was reported as variable component with variable irrigation scheduling methods with variable water amount[15]. Leaf area index result of this experiment was not affected by nitrogen rates. Total and tuber biomass dry weight results indicated similarity with report of Yuan *et al.*[17]. It also had correlations with results of Kashyap and Panda[18]. The reports of Darwish *et al.*[19] showed increment of dry mass with increment of water irrigated amount to field capacity. In addition, Mbarushimana[16] reported reduction of total biomass, tuber dry weight and above ground dry weight from stressed treatments. The results of the investigation revealed that increasing the amount of water from 60-100% (field capacity) increased both average tuber number and tuber fresh weight. This was because when the amount of irrigation water increases to the field capacity, the potato varieties get better supply that satisfy their needs for better tuber formation as water has significant effect on cell expansion, metabolism, translocation and part of plant body formation. These results agreed with findings of Nagaz *et al.*[20] and Onder *et al.*[21]. Similarly, increase in tuber yield with increase in water supply was reported by Kashyap and Panda[18], Yuan *et al.*[17] and Erdem *et al.*[22]. Similar results were indicated in Kang *et al.*[23] and Shiri-e-Janagrad *et al.*[24].

CONCLUSION

Several researchers reported the effect of nitrogen rates and irrigation regimes. Likewise, from these results it can be concluded that variety and irrigation regimes were significantly affected stem number, leaf area index, tuber to shoot ratio, dry matter, tuber number and fresh weight of the potato varieties while, the nitrogen rates were not influenced any measured parameter of the potato varieties significantly. It is better to produce jalane at 80% and Guassa at 100% irrigation regimes. Further research involving higher nitrogen rates and same irrigation regimes followed by post harvest activity and quality considerations in greenhouse and open field is suggested.

ACKNOWLEDGMENT

I would like to express my gratitude to staff members of Debre Zeyit Agricultural Research Centre and Jimma University who are working in soil and animal nutrition laboratory as well as horticulture section for extending their support during my laboratory work. Above all, I would like to thank the Almighty God for that made all things possible for me to finish the study.

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