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Effects of Organic and Inorganic Fertilisers on Growth, Yield, Nutritional Content, Quality and Shelf-Life of Irish Potato (*Solanum tuberosum* L.)

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Abstract: Organic and inorganic fertilisers can be used as nutrient sources which can enhance potato growth, yield, nutritional content and shelf-life. Combinations of chemical fertiliser NPK [4:3:5 (36.5)] with [3:0:5 (48.5)] as the control, cattle manure, goat manure, cattle manure combined with NPK [4:3:5 (36.5)], goat manure combined with NPK [4:3:5 (36.5)], goat manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] applied as topdressing, cattle manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] applied as topdressing and NPK [4:3:5 (36.5)] applied alone were used in this study. Goat and cattle manure were both applied at 40 t/ha, basal fertiliser NPK [4:3:5 (36.5)] at 900 kg/ha and NPK [3:0:5 (48.5)] applied as topdressing at 350 kg/ha and their interactions with plant growth, yield and nutritional quality were evaluated during a field experiment in 2018 with the use of a split-plot design with the 2x8 factorial arrangement of three replications in Eswatini. Shoot emergence occurred 20 days after planting. Plant height and number of branches increased linearly and significantly in response to manure and fertiliser application, where cattle manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] providing the highest plant height of 59.3 cm in Mondial cultivar. Mondial cultivar showed higher vegetative growth, yield and quality parameters when compared to BP1. Yield was significantly increased in response to manure and fertiliser application. Application of cattle manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] gave the highest marketable yield of 14.4 t/ha in Mondial cultivar with goat manure showing the lowest yield (5.3 t/ha) in Mondial cultivar. The application of cattle manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] induced the highest tuber dry matter content of 22.6% in BP1 cultivar. Application of fertiliser had no significant effect on nutritional content of tubers. However, increased levels of fertiliser applied increased the protein content in potato tubers. From the results of this study, it can be concluded that Eswatini farmers may supply cattle manure combined with NPK [4:3:5 (36.5)] and NPK [3:0:5 (48.5)] as a topdressing for high yield and quality of potatoes and also cultivar Mondial is recommended for production due to its higher yields and quality.

Key words: Cattle Manure, Chemical Fertiliser · Goat Manure · Marketable Yield · NPK · Nutritional Content · Potato · Shelf-Life · Sustainable Development

INTRODUCTION

Irish potato (*Solanum tuberosum* L.) is a herbaceous annual plant which belongs to the Solanaceae family. It is grown for its edible tubers which are very rich in starch and is native to the Andes [1]. Growth, yield, shelf-life and nutritional content is directly affected by nutrient source and supply, management, environmental factors and variety [2]. Potato is one of the major world food crops due to its capacity to produce high yields per unit area per unit time [3]. In Eswatini, even though most parts of the country have suitable soils and favourable climate for potato production, most soils especially in the Highveld and the wet Middleveld are strongly acidic to acidic in reaction due to the high rates of leaching of bases owing to high rainfall and poor soil management practices. Soils in the Lowveld are sodic and saline posing another problem for Irish potato production [4].

Nutrient supplementation can be an effective remedy to lack of sufficient nutrients. In the past agricultural production was characterised with the use of inorganic fertilisers which supplies the soil with the required

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nutrients which are readily absorbed by plants thus no time required for decomposition as compared to organic sources. However, the price of inorganic fertilisers in Eswatini has escalated beyond the capacity of the majority of the farmers. Oad *et al*. [5] observed that continuous use of mineral fertilisers creates a potential polluting effect on the environment.

Low soil fertility is one of the major constraints limiting potato production in Africa, hence increased and sustainable production means are required for suitable potato production. The intense use of inorganic fertiliser and continuous cropping, abandoning crop rotation and reduced use of organic manures has detrimental effects on the soil [2]. The use of inorganic fertilisers results in an overall reduction in total crop productivity. The use of inorganic fertiliser combined with organic fertiliser might be an answer for those farmers complaining of tremendous yield reduction despite the application of inorganic fertilisers to their farms [4].

The importance of organic fertilisers is being realized again because of the high cost of inorganic fertilisers and their (inorganic fertilisers) long term adverse effect on soil physical and chemical properties. Besides supplying macro- and micro-nutrients to the soil, organic fertilisers also improves the physio-chemical properties of the soil [6]. Cattle manure and goat manure are some of the most effective external fertiliser sources whose positive effects on potato yield have been studied [7]. However, unless it is integrated with inorganic fertilisers, the use of organic fertilisers alone may not fully satisfy crop nutrients demand, especially in the year of application [5]. Therefore, farmers should tackle the problem by application of both inorganic and organic fertiliser combined at the appropriate rate. Farmers in Eswatini are conscious of integrating inorganic and organic fertilisers but do not, however, know the best integration combinations that can improve potato productivity [2].

Most of the soils in Swaziland especially in the Middleveld and Highveld, which are high rainfall receiving areas are strongly acidic due to high rate of leaching and poor soil management. A nutrient imbalance exists in such soils, therefore, external organic and inorganic nutrient sources are required to supply nutrients to the soils [8]. Inorganic fertilisers (mineral fertilisers) are the most effective and convenient way to improve soil fertility. However, the mineral fertilisers have not entirely solved the problem of nutrient imbalances in the soil which leads to reduction in crop productivity. Even though mineral fertilisers add nutrients to the soil, soil health and productivity is not sustained. Organic fertilisers improve the soil health and also increase its productivity. Therefore, to achieve a sustained soil productivity and subsequent increase in crop growth and yield, calls for the exploitation of various alternative sources of soil fertility improvement and management strategies have been made [9].

Strategies to improve soil fertility have been employed to supply nutrients by means of organic and inorganic fertilisers. Mineral fertilisers have been the mostly widely used to improve crop productivity. However, it poses a greater threat to the environment and has residual effects on the harvested crop. The combined use of organic and inorganic fertilisers can be a harmonious and most productive method of nutrient supply as a means to increase yield and productivity of crops and at the same time maintaining a sustainable environment [10]. The objective of this study was to investigate the effects of organic and inorganic fertilisers on growth, yield, nutritional content, quality and shelf life of Irish potato.

MATERIALS AND METHODS

Experimental Site: The experiment was conducted at the Malkerns Research Station (MRS), in the Kingdom of Eswatini under the Ministry of Agriculture, between May and September 2018. The site is located at Malkerns, Manzini region in the Middleveld agro-ecological zone. The site is situated at 26°34'0.01" S and 31°10'59.99" E. The average altitude of this area is 732 m above sea level and the average rainfall is 800 mm/year mostly falling between October and April. It has mean summer temperature of 27°C and winter temperature of about 15°C. The soils are generally the Malkerns series which are Oxisol (M-set) type [11].

Experimental Design, Treatments and Procedures: Mondial and BP1 potato seeds (tubers) were purchased at Potato Seed Production, Lydenburg (Mashishing), South Africa. Two potato cultivars, Mondial (V_1) and BP1 (V_2) were subjected to different combinations of fertiliser treatments, which included NPK [4:3:5 (36.5)] + NPK [3:0:5 (48.5] as control (T_1), NPK [4:3:5 (36.5)] (T_2), cattle manure(T_3), cattle manure + [4:3:5 (36.5)] (T_4), cattle manure + [4:3:5 (36.5)] + [3:0:5 (48.5] (T_5), goat manure (T_6), goat manure +[4:3:5 (36.5)] (T_7) and goat manure + [4:3:5 (36.5)] + [3:0:5 (48.5] (T_8). Goat manure and cattle manure were applied 6 weeks before planting at 40 t/ha, NPK [4:3:5 (36.5)] also applied as topdressing at 900 kg/ha and NPK [3:0:5 (48.5] applied as topdressing at 350 kg/ha. Split-plot design arrangement was used for the 2 x 8 factorial experiment with three replications. All management practices including weeding, pest control and irrigation were done as per general requirements of potato production.

The experimental field was divided into three blocks with each block having 16 plots and each plot was 4.5 x 5.0 m (22.5 m^2). Plots were separated by 1.0 m foot-paths. Intra-row spacing was 30 cm and inter-row spacing was 90 cm, with each plot having five rows. The three inner rows were used for data collection, whilst the two outer rows were regarded as guard rows. Plots were supplied with basal dressing as per requirement of treatment, thus goat manure, cattle manure and chemical fertiliser NPK [4:3:5 (36.5)] at specified rate using banding method. Topdressing was done two weeks after seedling emergence.

Data Collection and Analysis: Data collected on growth parameters included shoot emergence plant height, number of branches and chlorophyll content, yield parameters included marketable yield, non-marketable yield, number of tubers per plant, individual tuber weight and weight of tubers per plant, tuber quality included tuber dry matter content, tuber moisture content, nutritional content such as carbohydrate, protein, iron and potassium contents, sprout to tuber weight ratio, physiological weight loss and shelf-life. The data were subjected to analysis of variance (ANOVA) using statistical package GENSTAT [12]. Where significant differences were detected, mean separation was done using Duncan's New Multiple Range Test (DNMRT) at P=0.05 [13].

RESULTS AND DISCUSSION

Effects of Organic and Inorganic Fertilisers on the Growth Parameters: The effect of organic and inorganic fertilisers were found to be significant ($P<0.05$) in all vegetative growth parameters studied, which included shoot emergence, plant height, number of branches and chlorophyll content. Mondial variety had significantly ($P<0.05$) higher vegetative growth parameter values when compared to BP1.

Shoot Emergence: Application of cattle manure + [4:3:5 (36.5)] + [3:0:5 (48.5)] and goat manure + [4:3:5 (36.5)] + [3:0:5 (48.5)] significantly ($P<0.05$) hastened shoot emergence compared to other treatment, thus reduced days to emergence (Table 1). These findings are in agreement with those of Hay and Walker [14], who found that sprout emergence is greatly dependant on temperature and mineral nutrition. According to Hay and Walker [14], shoot emergence is primarily determined by soil temperature, thus manure has the ability to increase the temperature of the soil leading to increased sprout emergence percentage. Pre-planting application of fertiliser tends to increase osmotic pressure of the soil solution. Varieties also differ considerable in terms of shoot emergence, as Mondial variety sprouted faster than BP1 variety. White [15] concluded that increased potassium supply to potato seeds tends to increase

Table 1: The effects of organic and inorganic fertilisers on shoot emergence percentage of Mondial and BP1 potato varieties at different days after planting (DAP). Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT.

	Days after planting (DAP)				
Type of fertiliser	20	25	30	35	40
T_1V_1	34.4cde	82.2a	93.3ab	95.56ab	100a
T_1V_2	8.9f	44.4cd	63.3def	83.33ab	94.44ab
T_2V_1	46.7bc	87.8a	96.7ab	96.67ab	100a
T_2V_2	7.8fg	40de	77.8cde	86.67ab	97.7a
T_3V_1	47.8ab	91.1a	97.8a	97.78ab	97.7a
T_3V_2	10fg	46.7cd	76.2cde	90b	96.67a
T_4V_1	55.6ab	93.3a	96.7ab	97.78ab	100.0a
T_4V_2	13.3fg	44.4cd	81.5bcd	87.78b	100.0a
T_5V_1	61.1a	90.0a	96.7ab	97.78ab	100.0a
T_5V_2	22.2ef	60.0cd	90.0abc	94.44b	100.0a
T_6V_1	42.2bcd	81.1a	100.0a	100.0a	100.0a
T_6V_2	13.3fg	50.0de	83.3cde	96.67ab	100.0a
T_7V_1	20.1ef	64.4bc	92.2ab	96.67ab	100.0a
T_7V_2	6.7g	25.6bc	57.8f	77.78c	94.44ab
T_8V_1	33.3ef	77.8ab	94.4ab	97.78ab	100.0a
T_8V_2	4.4g	22.2e	58.9ef	82.22ab	96.67a

Table 2: The effects of organic and inorganic fertilisers on the number of branches of Mondial and BP1 potato varieties at different weeks after planting (WAP) Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT

	Weeks after planting							
	7		8		9		10	
Type of fertiliser	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	5.67ab	2.67c	6.00ab	2.67c	6.00ab	2.67c	6.00a	3.00b
T_2	6.00ab	2.67c	7.00a	3.33c	7.00a	3.67c	7.00a	3.67b
T_3	5.33ab	2.33c	5.33b	2.67c	5.33ab	2.67c	5.33a	2.67b
T_4	5.00b	2.67c	6.00ab	3.33c	6.33ab	3.33c	6.33a	3.33b
T_5	6.33a	2.33c	6.67ab	2.33c	6.67ab	2.33c	6.67a	2.33b
T_6	5.33ab	2.33c	6.00ab	2.33c	6.33ab	2.33c	6.33a	2.33b
T_7	5.33ab	2.67c	6.33ab	2.67c	6.67ab	2.67c	6.67a	2.67b
T_8	4.86a	2.33b	4.89b	2.33b	4.95b	2.33c	4.95b	2.67b

Table 3: The effects of organic and inorganic fertilisers on the plant height (cm) of Mondial and BP1 potato varieties at different weeks after planting (WAP). Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT.

	Weeks after planting							
	7		8		9		10	
Type of fertiliser	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	37.6cd	33.8bc	41.1d	38.8bc	52.2a	47.7a	52.3a	48.0a
T_2	37.5ab	33.2bc	41.9ab	38.27bc	42.73a	40.4ab	42.8b	40.4b
T_3	24.2cd	22.9d	31.6bc	27.5e	33.1ab	30.0ab	34.6b	31.1b
T_4	38.3a	40.3ab	43.4a	46.9a	46.5ab	48.2ab	48.6b	48.2b
T_5	40.8a	39.1ab	44.6a	43.8ab	55.2a	52.6ab	56.2a	53.2b
T_6	22.7d	22.8d	31.2bc	27.4cd	34.1ab	34.8ab	36.2b	35.2b
T_7	35.5a	34.1bc	45.9a	39.9bc	47.4ab	36.5ab	48.1b	37.1b
T_8	36.4a	33.7bc	43.4ab	45.0ab	53.1a	52.6ab	54.4b	53.1b

enzyme activity leading to increased metabolism thereby hastening shoot emergence. Bhattarai and Swarnima [16] confirmed that potassium aids in maintaining osmotic potential which enhances water uptake and root permeability, control ionic balances, regulate plant stomata and activate enzymatic processes. This therefore contributes largely to increased rates of shoot emergence if potassium concentration is increased.

Number of Shoots per Plant: There were significant (P<0.05) differences in number of shoots per plant between Mondial and BP1 throughout the growing period of the potato plants. However, there were no significant (P>0.05) differences among fertiliser treatments on number of branches. At 10 weeks after planting (WAP), cultivar Mondial provided with NPK [4.3.5 (36.5)] + NPK [3.0.5 (48.5)] fertiliser gave the best results (7 shoots per plant) with cultivar BP1 provided with NPK [4.3.5 (36.5)] + NPK [3.0.5 (48.5)] had the lowest number of branches (3) (Table 2), which was less than a half that obtained from Mondial. The results obtained are in agreement with findings obtained by Roy and Singh [17]. They recognized the role of N in branching-tillering phenomenon. In the current study, the lack of significant difference in number of shoots per plant due to treatments could probably be attributed to genetic make-up of the varieties. The results obtained are also in agreement with findings by De la Morena *et al.* [18], who concluded that the number of active Irish potato haulms may vary a lot depending on seed age, mass, size and the number of growing eyes or sprouts; but the number of eyes, shoots and distribution are characteristic of the variety.

Plant Height: There were no significant (P>0.05) differences in number of branches between Mondial and BP1 cultivars throughout the growing period. However, there were significant differences in plant height due to fertiliser treatments. Application of cattle manure + [4:3:5 (36.5)] + [3:0:5 (48.5)] resulted in the highest (56.2 cm) plant height in cultivar Mondial (Table 3). This results are in agreement with findings by Mohammed *et al*. [19], who observed that 10 t/ha FYM + 111 kg/ha N + 92 kg/ha P_2O_5 gave the highest plant height (95.6 cm) as compared to the control. They concluded that increase in levels of

Table 4: The effects of organic and inorganic fertilisers on the chlorophyll content of Mondial and BP1 potato varieties at different weeks after planting (WAP). Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT

	Weeks after planting							
	7		8		9		10	
Type of fertiliser	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	40.5a	36.8a	40.7ab	37ab	43.5a	40.3a	20.8a	38.1a
T_2	44.1a	33.0a	40.7ab	33.1ab	37.1a	26.3b	21.4a	22.1b
T_3	32.0a	33.8a	28.4bc	32.9bc	17.7b	27.2b	17.8b	19.5b
T_4	40.8a	40.1a	42.0ab	40.4ab	33.1a	34.2a	23.8a	28.8a
T_5	41.3a	38.7a	51.8a	43.5a	41.6a	44.6a	21.3a	28.1a
T_6	31.5a	33.6a	32.0ab	30.7bc	19.9a	24.5a	15.7a	25.2a
T_7	37.3a	45.9a	43.1ab	46.4ab	41.5a	42.9a	20.6a	29.1a
T_8	37.7a	40.8a	54.6a	44.6ab	45.6a	39.8a	30.6a	33.2a

nitrogen supplied to plants triggered cell division and enlargement which might directly have positively impacted plant height. This significant difference might also be probably due to adequate supply of the required nutrients from the organic and inorganic fertilisers. The results from this study are also in agreement with findings by Shalini *et al*. [20], who stated that the application of organic manure with inorganic fertilizer significantly increased growth and vigour of the plants over application of inorganic fertilisers alone. Assefa *et al*. [21] reported that with increase in combined fertiliser application of NPK fertiliser and farmyard manure in garlic, the maximum plant height was obtained with use of 70% of the recommended dose of 185 kg/ha urea in nitrosol and 20 t/ha farmyard manure.

Chlorophyll Content: There were no significant (P>0.05) differences observed between chlorophyll content of Mondial and BP1 varieties at 7 WAP Similarly, there were no significant (P>0.05) differences in chlorophyll content of leaves due to fertiliser treatment (Table 4). However, at 8 WAP significant (P<0.05) differences were observed on the leaf chlorophyll content due to fertiliser treatments. In the current study, application of cattle manure + [4:3:5 (36.5)] + [3:0:5 (48.5)] and goat manure + [4:3:5 (36.5)] + [3:0:5 (48.5)] induced significantly (P<0.05) higher chlorophyll content as compared to the control. Chlorophyll content increased with the increased levels of nitrogen absorbed by plants. Similar findings were obtained by Güler [22], who concluded that there was a significant linear relationship (r^2=0.90) between nitrogen rate applied and leaf chlorophyll content. Results obtained in the current study at 9 and 10 WAP show significant decline in leaf chlorophyll content. This was in agreement with findings by Güler [22], who concluded that leaf chlorophyll content declines with age since leaf N levels also decrease. This result is also in agreement with findings by Vos and Born [23] and Najm *et al*. [24], who observed a positive relationship between leaf nitrogen levels and chlorophyll content.

Effects of Organic and Inorganic Fertilisers on the Yield Parameters: The effect of organic and inorganic fertilisers was found to be significant (P<0.05) on yield parameters such as number of tubers per plant, marketable tuber yield, weight of tubers per plant and individual tuber weight (Table 5). Variety Mondial was significantly superior compared to BP1 in most of the yield parameters (Table 5).

Number of Tubers per Plant: There were significant (P<0.05) differences in number of tubers per plant between varieties Mondial and BP1. Similarly, there were significant (P<0.05) differences observed on the average number of tubers per plant due to different fertiliser application, with plants provided with goat manure combined chemical fertiliser [4:3:5 (36.5)] and also cattle manure + [4:3:5 (36.5) + 3:0:5 (48.5)] showing the highest number of tubers (17) (Table 5). These results indicate an increase in number of tubers which may be attributed to increased vegetative growth which could have been brought about by increased nutrient supply to the plants, which positively affects the photosynthetic capacity. Similar findings were reported by Zewide *et al*. [9], who reported that increased levels of phosphorus and nitrogen increased number of tubers per plant. This result is also in agreement with finding by Güler [22], who reported that increased levels of N also significantly increased number of tubers per plant. This result is also in line with findings of Uwah and Eyo [25], who reported that increasing levels of goat manure applied on sweet corn increased the number of grains per ear. Manure improves the soil

Table 5: The effects of organic and inorganic fertilisers on number of tubers per plant, tuber yield per plant (g), marketable tuber yield (t/ha), unmarketable tuber yield (t/ha) and individual tuber weight of Mondial and BP1 potato varieties. Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT

Type of fertiliser	Number of tubers per plant		Tuber yield per plant (g)		Marketable tuber yield (t/ha)		Unmarketable tuber yield (t/ha)		Individual tuber weight (g)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	13.0bc	8.0de	617ab	507ab	10.1bc	7.1cde	1.5ab	1.2ab	47e	63ab
T_2	12.5bc	7.0de	544ab	391b	10.2bc	7.1cde	1.4ab	1.0ab	42.5ef	57abc
T_3	10.0cd	5.5e	315b	284b	5.7e	5.4e	0.8b	0.8b	34.0fg	53bcd
T_4	13.0ab	6.5de	668ab	382b	12.0ab	8.2cde	1.5b	1.4ab	53.0cde	57abc
T_5	16.5a	8.5de	854a	556ab	14.4a	10.6bc	1.4ab	1.5ab	52.5de	71a
T_6	13.0bc	6.5e	402ab	297b	6.4de	5.3e	1.4ab	0.8b	32.3g	49bcd
T_7	16.5a	10.5d	631ab	611ab	10.7bc	9.6bcd	1.3ab	1.2ab	38.5efg	61abc
T_8	14.5ab	9.5de	672ab	632ab	11.9ab	9.6bcd	1.9a	1.3ab	45.5ef	67a

structure and thus microbial activity is accelerated, which ultimately enhances nutrient absorption, thus potato yield was increased in the form of tubers [26].

Tuber Yield per Plant: The highest tuber yield per plant (854 g) was recorded from plants provided with cattle manure + [4:3:5 (36.5) + 3:0:5 (48.5)] (T_5) on variety Mondial, whilst the lowest (284 g) was recorded on variety BP1 supplied with cattle manure (Table 5). The results obtained in the current study indicate that tuber yield per plant is dependent on the nutrient content supplied. Findings obtained in the study are in agreement with findings by Uwah and Eyo [25], who found that increased levels of combined application of farmyard manure + K_2O significantly increased tuber yield per plant. Similar findings were also reported by Ahmed *et al*. [27], Baniuniene and Zekaite [28] and Najm *et al*. [24], whose results indicated that nitrogen fertilizer, cattle manure and their combination had highly significant effects on tuber yield.

Marketable Tuber Yield: The highest marketable tuber yield (14.38 t/ha) was obtained from plants provided with cattle manure + [4:3:5 (36.5) + 3:0:5 (48.5)] in variety Mondial whilst the lowest (5.33 t/ha) was obtained from those fertilised with goat manure (Table 5). The results obtained indicate that productivity of potato plants was significantly affected by the interaction between different manures and different inorganic fertilisers. Yang *et al*. [29] attributed the higher yield in combined application mineral fertilisers with cattle manure largely to the prolonged release and addition of more macro- and micro-nutrients, thereby promoting better crop growth and marketable tuber yield of potato. These results are in agreement with findings by Ababiya [30], who observed higher potato tuber yield under integrated use of cattle manure and inorganic fertiliser source. Similarly, Islam *et al*. [31] observed increased tuber yield in potato crop when the crop was supplied with cow dung and poultry manure. Shanward *et al*. [32] reported that combination of N and P fertilizer each at 50 kg/ha with 5 t/ha farmyard manure increased yields significantly. Similarly, manure at half the recommended rates and farmers practice also resulted in more vigorous plant growth compared to applying FYM alone.

Average Tuber Weight: The highest tuber weight (70.7 g) was observed from plants provided with cattle manure + [4:3:5 (36.5) + 3:0:5 (48.5)] (T_5) in variety BP1 whilst the lowest (32.3 g) was obtained from those fertilised with goat manure (Table 5). This result indicate that increased nutrient supply to plant increases vegetative growth which positively impacts yield. This result is in agreement with findings by Zewide *et al*. [9], who reported that increased levels of N increases tuber weight. Shunka *et al*. [33] concluded that regardless of the variety, the mixture of organic and inorganic fertiliser positively influences yield and at the same time improving the crop qualities. According to Kumar *et al*. [34], increased nitrogen levels leads to increased foliage automatically increases photosynthesis rate, thereby leading to more photosynthates in tuber during translocation.

Effects of Organic and Inorganic Fertilisers on the Tuber Quality Parameters: The effect of organic and inorganic fertilisers was found to be significant (P<0.05) on the tuber quality parameters which included dry matter (DM) content and moisture content. Tuber quality of variety Mondial was found to be significantly (P<0.05) different from BP1.

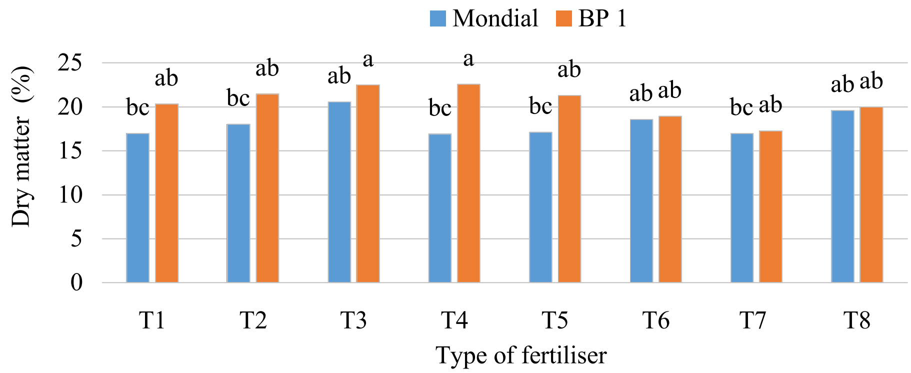

Fig. 1: The effects of different fertilisers on the tuber dry matter content of Mondial and BP1 varieties. Bars followed by the same letter are not significantly different at P= 0.05. Mean separation by DNMRT.

Dry Matter Content: Significant (P<0.05) differences were observed in tuber DM due to fertiliser treatment. Similarly, there were (P<0.05) significant differences observed between DM of variety BP1 and Mondial. The highest DM content (20.6%) in Mondial was found in plants provided with cattle manure and the second highest (19.97 %) DM content was found on tubers of plants provided with goat manure + [4:3:5 (36.5) + 3:0:5 (48.5)] in cultivar Mondial (Figure 1). This result indicate that tuber DM content could probably have been determined by varietal difference (genetic make-up) and also the fertiliser treatment. Increase in fertiliser levels supplied led to decrease in DM content even though fluctuations were evident in some treatments. These results are in agreement with findings by El Sayed *et al*. [35], who found that there were no significant differences on tuber dry matter as influences by organic and inorganic fertiliser combination. Similar results were obtained by Simson *et al*. [36], who concluded that indeed DM content is largely influenced by variety and increasing fertiliser levels clearly reduces DM content. Bhattarai and Swarnima [16] also reported that increasing levels of K supplied to potatoes leads to decrease in DM content. According to Goffart *et al*. [37], excessive doses of N leads to DM accumulation into other plant parts other than the tubers.

Effects of Organic and Inorganic Fertilisers on the Tuber Nutritional Content: The effect of organic and inorganic fertiliser were not significantly (P>0.05) different on all the nutritional parameters, which included protein percentage, carbohydrate, potassium (K) content and iron (Fe) content. Similarly, no significant (P>0.05) differences were observed between nutritional content of BP1 and Mondial varieties (Table 6).

Carbohydrate Content: The results obtained showed that combined application of organic and inorganic fertilisers resulted in the highest carbohydrate content in both varieties. The increase in carbohydrate content in response to increased fertiliser application may be attributed to enhanced growth and photo-assimilation due to better nutrient uptake. This leads to sugar (glucose) produced during photosynthesis converted to starch as food reserves [38]. These results are in agreement with findings by Susan *et al*. [39], who reported that balanced application of NPK at 100:50:100 kg/ha combined with FYM at 12.5 t/ha was beneficial in maintaining starch content of cassava tubers.

Protein Content: Results obtained in the current study indicated that combined application of organic and inorganic fertilisers increased tuber protein content (Table 6). This high protein content in tubers from plants provided with cattle and goat manure combinations was largely attributed to their ability of supplementing N supply into the soil for uptake by plant. Inorganic fertilisers usually positively impact protein content of tubers compared to organic fertilisers due to their increased N supply to the soil [40]. Kandil *et al*. [41] observed that combined application of mineral nitrogen fertilizer (238 Kg/ha N) and chicken manure (158 Kg/ha N) increased average protein content in tubers, which ranged from 15.21 to 17.29%. Similarly, Öztürk *et al*. [42] reported that the crude protein contents of tubers significantly increased with increasing nitrogen dose. Kumar *et al*. [34] also reported that increasing nitrogen supply indeed increases the protein content in tubers.

The results obtained are in agreement with findings by Bhattarai and Swarnima [16], who reported that tuber nutritional content does not only depend on fertiliser

Table 6: The effects of organic and inorganic fertilisers on the carbohydrate content, protein percentage, potassium content and iron (Fe) content of Mondial and BP1 potato varieties. Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT

	CarbohydrateContent (%)		Protein percentage (%)		Potassium content (mg)		Iron content (mg/kg DM)	
Type of fertiliser	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T1	9.6a	10.5a	8.3a	7.1abc	342a	493a	28.3a	42.0a
T2	9.8a	9.9a	6.8abc	5.4bc	596a	471a	38.6a	36.5a
T3	12.4a	9.5a	5.3c	5.0c	530a	768a	48.8a	41.9a
T4	8.76a	9.9a	8.0a	5.3c	745a	436a	41.8a	61.6a
T5	10.1a	10.3a	8.0a	8.1a	550a	630a	50.2a	56.5a
T6	9.1a	8.7a	5.2c	7.9ab	746a	348a	40.9a	59.6a
T7	8.5a	10.3a	6.9abc	7.9ab	536a	632a	43.9a	55.4a
T8	12.0a	12.1a	8.0a	6.9abc	731a	557a	53.4a	48.1a

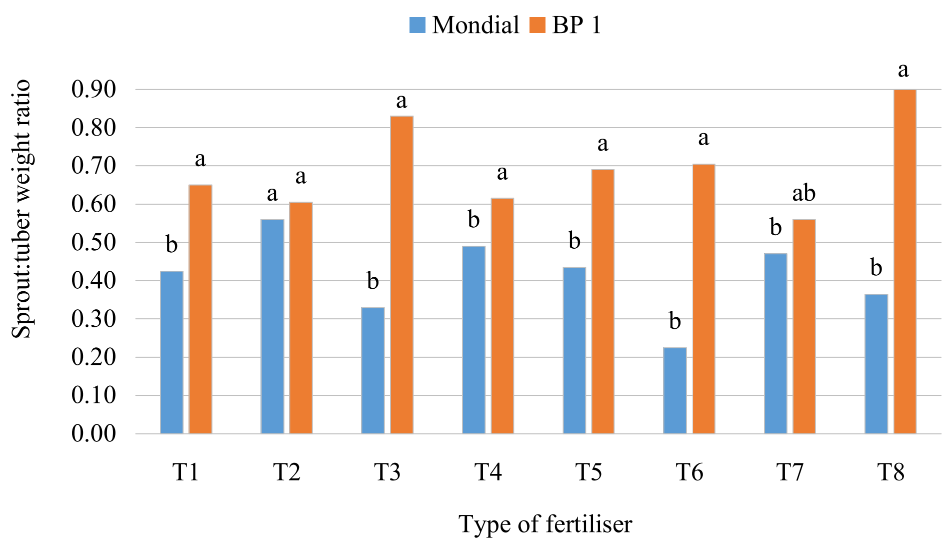

Fig. 2: The effects of different fertilisers on the sprout to tuber weight ratio of Mondial and BP1 varieties. Bars followed by the same letter are not significantly different at P=0.05. Mean separation by DNMRT.

dose but also on the source and variety. Kammlade [43] also reported that tuber nutritional content is largely dependent on the genetic make-up other that the fertiliser dose. Fernandes *et al*. [44] also found that nutritional content of tubers as much as it responds to fertiliser dose to a certain extent, it is largely dependent on the variety and its interaction with the environmental conditions.

Effects of Organic and Inorganic Fertilisers on the Shelf-life of Potato Tubers: The effect of organic and inorganic fertilisers on the sprout: tuber weight ratio were not significantly (P>0.05) different. However, significant (P<0.05) differences in sprout to tuber weight ratio were observed between variety Mondial and BP1 (Figure 2). Significant (P<0.05) differences were observed on the physiological weight loss (PWL) of tubers due to fertiliser treatments. Similarly, significant (P<0.05) differences in PWL of tubers were recorded between variety Mondial and BP1.

Sprout: Tuber Weight Ratio: The results obtained indicate that variety BP1 had higher sprout to tuber weight ratio compared to Mondial. The effects of organic and inorganic fertilisers were inconsistent according to the results obtained. However, application of manure and combined application gave higher values as compared to the control (Figure 2). This is largely due to the fact that sprouting during storage is dependent on the pre-harvest integrated nutrient management during growth and also the variety. These results are in agreement with findings by Biruk-Masrie *et al*. [45], who reported that tubers obtained from pre-harvest treatments of N, P and cattle manure produced a high sprout to tuber weight ratio. Sowley *et al*. [46] conducted a similar study on sweet potato in Kenya and similar conclusions were made where results indicated that sprouting percentage is largely affected by variety more than the fertiliser treatment applied. Kandil *et al*. [41] observed that combined application of 20 t/ha cattle manure with 396 kg/ha N

Table 7: The effects of organic and inorganic fertilisers on the physiological weight loss of tubers of Mondial and BP1 potato varieties at different days of storage (DOS). Within a column means with the same letter are not significantly different at P<0.05. Mean separation by DNMRT

Type of fertiliser	15		30		45		60		90 days of storage (DOS)	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	2.2a	2.2a	4.6a	4.7a	7.8a	8.3a	9.9a	10.3a	12.5a	13.1a
T_2	2.2a	2.0a	7.1a	6.7a	8.8a	7.6a	9.9a	9.3a	10.5a	10.3a
T_3	2.3a	2.1a	6.6b	5.9a	7.9a	7.3a	8.2a	8.3a	8.5a	8.5a
T_4	2.3a	2.1a	6.3b	7.1a	7.0b	7.9a	7.6b	8.6a	8.5a	8.5a
T_5	2.2a	2.1a	6.83a	6.8a	8.0a	7.9a	9.0a	9.3a	8.8a	10.3a
T_6	2.3a	2.1a	5.9b	5.9b	6.2b	6.4b	7.2b	7.4b	7.4b	7.5b
T_7	2.3a	2.2a	7.4a	7.3a	8.5a	8.3a	8.9a	9.2a	9.7a	10.1a
T_8	2.8a	2.0a	8.3a	6.9a	8.9a	8.3a	10.2a	9.5a	10.5a	10.3a

resulted in the highest value of sprout length (5.34 cm) after storage compared to sprout length (3.71 cm) obtained from the tubers grown with manure alone.

Physiological Weight Loss: Significant PWL of tubers during storage could be caused by of loss of moisture from the tubers and depletion of carbohydrate reserves as a result of respiration [47]. The results obtained in this study indicated that physiological weight loss of tubers was affected by both pre-harvest fertiliser treatment and the variety used. Tubers of variety BP1 showed the highest weight loss in most of the treatments compared to Mondial (Table 7). These results are in agreement with findings by Mehta and Singh [48], who concluded that the combined application of NPK and FYM resulted in higher storage losses compared with FYM alone.

CONCLUSION

Potato plant growth and tuber yield is largely dependent on the fertiliser supply and source, environmental conditions and genetic make-up. The current study has revealed that cattle manure + NPK [4:3:5 (36.5)] + NPK [3:0:5 (48.5)] increased potato tuber yield. Variety had significant effects on the yield. Based on the current study, increase in fertiliser application had an inverse effect on the shelf-life of potato tubers. Combined application of organic and inorganic fertilisers improved the tuber quality and nutritional content of potato. Increased supply of fertiliser led to reduction in shelf-life of potato tubers. Moreover, application of animal manure induced significant increases in the weed infestation of the fields. An appropriate combination of inorganic fertilisers and manures is recommended for sustainable plant growth and development.

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