EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF POTATO (SOLANUM TUBEROSUM L.)

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ABSTRACT

To study the effect of integrated nutrient management on the growth and yield attributes of potatoes, this field experiment was carried out at Mangalsen Municipality, Thatikhand, Achham district, Nepal from February 2023 to June 2023. The experiment used a single-factor Randomized Complete Block Design (RCBD) with three replications and seven treatments. Different types of organic and inorganic fertilizers and their combination were used as treatment which are; T1: (RDF @ 100:100: 60), T2: (RDF @ 75% + FYM @ 20 ton/ha), T3: (RDF @ 75% + Vermicompost @ 8 ton/ha), T4: (RDF @ 75% + FYM @ 2ton/ha + Sulphur @ 20kg/ha), T5: (RDF @ 75% + FYM @ 2 ton/ha + Zincsulphate @ 20kg/ha), T6: (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20kg/ha + Zincsulphate @ 20kg/ha) and T7: (Control). The variety of potatoes used for research was "Khumal Seto" as it is recommended for cultivation in the high-hill and mid-hill regions of Nepal. A significant difference in plant germination, plant height, leaf number, stem number, canopy diameter, and yield attributing characters such as total number of tuber per hill, average weight of tuber, and total yield was observed among the treatments under observation. The yield parameters such as total number of tuber per hill (8.33), weight per tuber (0.08 gm), marketable tuber yield (10.24 Kg), and total yield (28.33 mt/ha), and growth parameters such as plant germination (21), plant height (39.2 cm), number of leaves (29.2), number of stems (14.26), and plant canopy (69.06) were observed highest in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20kg/ha + Zincsulphate @ 20kg/ha) at 75 DAS and lowest of these were measured at 45DAS in treatment Control. Therefore, Treatment RDF@ 75% + FYM @ 2ton/ha + Sulphur@ 20kg/ha + Zincsulphate @ 20kg/ha) is best for farmers in Achham to improve the growth and yield of potatoes.

Keywords: *canopy diameter, FYM, marketable tuber*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most significant commercial crops grown in Nepal for both culinary and other reasons and is consumed as vegetables, processed foods, starch production, etc. (Asano & amp; Tamiya, 2016). According to the carbon dating of starch grains noticed in archaeological revealing in the Andean regions

of Peru and Bolivia, potatoes were used as food at least 8,000 years ago (Brown, 1993). Belonging to the Solanaceae family, this significant vegetable crop contains approximately 75–80% water, 16–20% carbohydrates, 2.5–3.2% crude protein, 1.2–2.2% true protein, 0.8–1.2% mineral matter, 0.1–0.2% crude lipids, 0.6% crude fiber, and several vitamins (Reddy et al., 2018). Potato is the world's third most consumed food crop and has been recognized by the Food and Agriculture Organization of the United Nations as a food security crop.

In developing countries, where potato is an extremely imperative food source, income source as well as source of employment, consumption is expanding gradually (Lutaladio & amp; Castaldi, 2009). Potato is considered one of the most important non-grain food commodities, with a total global production of 376 million tonnes in 2019 (Food and Agriculture Organization Corporate Statistical Database, 2021). China ranked first in the world with the production of 91 million tonnes of potatoes in 2019, which is equivalent to nearly 25% of the total world's production (FAOSTAT, 2021). Nepal contributed only 0.84% of the global production of potatoes (FAOSTAT, 2021). In Nepal, Potato is grown in 198,788 ha with a production of 3,325,231 mt and productivity of 16.79 mt/ha (MoALD, 2021/22). Achham covers an area of 1,692 km^2. The total landform of the district can be divided as 90% area is mid-hill and 10% is high-hill. For the majority of people, subsistence agriculture mainly small-scale livestock farming is their primary source of income, with 61% of the population employed in this field. Due to poor levels of agricultural productivity, the majority of households endure significant food shortages for a considerable portion of the year. (District profile, Achham). Major crops grown in this district are Rice, Wheat, Maize, Potato, Citrus, Kiwi, Walnut, etc.

Integrated Nutrient Management (INM) is a sustainable approach to agricultural management that combines the use of organic and inorganic sources of nutrients to maintain soil fertility and improve crop yields (Olsen et al., 2019). INM involves the integration of various nutrient sources, such as chemical fertilizers, organic manures, and biofertilizers, to provide a balanced and adequate supply of essential plant nutrients (Kumar et al., 2020). The adoption of INM practices has been reported to result in several benefits, including improved soil health, increased nutrient use efficiency, and enhanced crop productivity (Shukla et al., 2018). The potato (*Solanum tuberosum* L.) is an important food crop worldwide and is widely grown in diverse agroecosystems. The effect of INM on the growth and yield attributes of potatoes has been widely studied. INM has been found to positively influence potato growth and yield attributes, such as plant height, tuber size, and yield (Kumar et al., 2020; Yawar et al., 2021). Furthermore, INM has been reported to improve the quality of potato tubers by increasing the starch content and

reducing the incidence of diseases and pests (Shukla et al., 2018). Despite the potential benefits of INM, there is a need for further research to explore the specific effects of different INM practices on the growth and yield attributes of potatoes.

METHODOLOGY

The research was conducted from February to July of 2023 in the Achham district of Nepal, which represents the mid-hill region and has the potential for potato production. It covers an area of 1,692 km^2 and is located at Latitude: 29° 06' 24.57" N, and Longitude: 81° 17' 33.46" E. The research was conducted in Thantikhan, Achham as it is the major working site. Achham, located at an elevation of 923.84 meters (3030.97 feet) above sea level, boasts a Subartic, dry winter, cool summer climate. The district experiences a yearly temperature of 22.14ºC (71.85ºF), which is 0.14% higher than the average temperature of Nepal. With about 166.55 millimeters (6.56 inches) of precipitation annually, Achham is a place that offers plenty of opportunities to witness the beauty of nature. The district has 141.98 rainy days (38.9% of the time) annually.

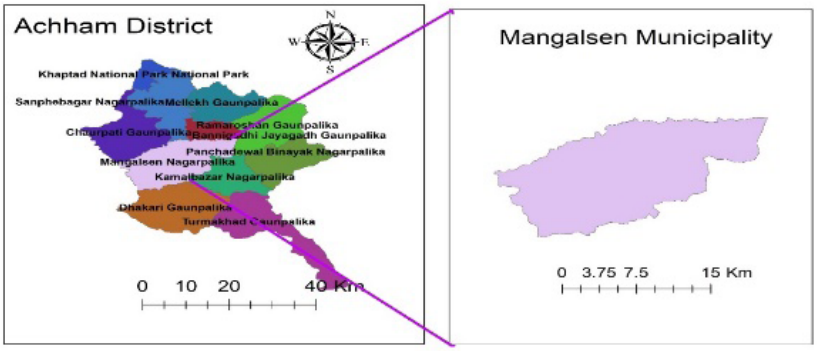

Figure 1. Map of research area in Achham district, 2023

Experimental design:

The experiment follows a single factorial RCBD design with 3 replications and 5 treatments. Each plot contains 24 plants, 5 of which were randomly selected. 5 plants were selected in an "X" shape to cover the whole plot area. Different types of organic and inorganic fertilizers and their combination were used as treatment which are; T1: (RDF @ 100:100: 60), T2: (RDF @ 75% + FYM @ 20 ton/ha), T3: (RDF @ 75% + Vermicompost @ 8 ton/ha), T4: (RDF @ 75% + FYM @ 2ton/ha + Sulphur @ 20kg/ha), T5: (RDF @

75% + FYM @ 2 ton/ha + Zincsulphate @ 20kg/ha), T6: (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20kg/ha + Zincsulphate @ 20kg/ha) and T7: (Control). The plot size is 2.4m x 1.5m. The spacing between replication was maintained at 1m and the plots at 0.5m. The total number of plots is 21, with 4 rows in each plot. There are 6 tubers in each row, making a total of 24 seed tubers per plot and 504 in the entire plot. The experiment covers an area of 128.7 m^2.

The field was prepared through deep plowing, leveling, and weed removal a week before the plantation. 21 plots were prepared with a detailed layout before sowing. Recommended organic and inorganic fertilizers were applied, including well-decomposed FYM and vermicompost. The recommended fertilizer doses included a half dose of urea, and a full dose of MOP, DAP, zinc sulfate, and sulfur. The split dose of urea was applied after 60 DAP. "Khumal Seto" variety of potato was used for the research experiment. According to the provincial agricultural diary, the recommended seed rate for potatoes was 20 tons/ha. For the research experiment, it was calculated that 504 tubers were used. Khumal Seto is resistant to blight, wart, and leaf roll virus. It is also tolerant to hail and drought. Khumal Seto is recommended for cultivation in the high-hill and mid-hill regions of Nepal. During the growing season, earthing up was done two or three times with the first earthing up being carried out around 3-4 weeks after planting, and the second and third earthing up occurring at around 2-3 week intervals. Regular monitoring of the research field was conducted to determine the incidence of insect pests and diseases. Appropriate measures were taken in response. Haulm destruction before harvest was often applied to reduce damage during harvesting. Before harvesting, the haulm was pulled or cut. It was evident that good skin formation after haulm destruction was quicker in potatoes that were close to maturity. Indicators of tuber maturity included complete vine death and the development of a "skin set." The potatoes were harvested after 10-15 days of dehaulming. Harvesting was carried out with the help of local tools like spades, khurpi, or kuto in small fields. For the evaluation, data were collected from the tagged plants at different times as required. Tuber weight was recorded using a digital weighing balance for accurate results. Five sample plants from each plot, excluding the border plants, were selected. From these, the following growth and yield parameters were studied. The statistical software packages Microsoft Office Excel and R-studio were used to analyze the data that was gathered during the experiment. Raw data processing was carried out using Microsoft Office Excel 2013 and data was analysed with R-studio. The doe biological research package was used for analyses and obtained data was tabulated. Analysis of variance was calculated using R studio.

OBSERVATIONS

Growth parameters

Measurements were taken at 15-day intervals, starting from 45 days after sowing.

Number of plant germination

After a week of sowing when the potato starts to germinate, data was taken in every alternate day by counting the number of plants that have germinated till all the plants germinate. Reading was taken at 30 DAS.

Plant height (cm)

Plant height was measured from the ground surface with the help of measuring tape at 45 DAS, 60 DAS and 75 DAS. Data were collected from the selected sample plants from each plot.

Plant Canopy (cm)

The canopy length from each selected sample plant was recorded with the help of measuring tape at 45 DAS, 60 DAS and 75 DAS.

Number of leaves per plant

The total number of leaves from each plant, excluding senescent and emerging leaves was recorded at 45 DAS, 60 DAS and 75 DAS.

Number of stems per plant

The total number of stems per plant of the selected plants in the unit plot was counted, and data were recorded at 15-day intervals from 45 DAS, 60 DAS and 75 DAS.

Yield parameters

Different yield parameters like average tuber number per hill, average tuber weight, marketable tuber yield, unmarketable yield and total tuber yield were recorded at the time of harvest.

Average tuber number per hill

It was explained as the total number of tubers harvested from hills divided by the number of plants harvested.

Average tuber weight (gm)

It was recorded as the ratio of the weight of tubers per plant per hill to the number of tubers per plant per hill, which was expressed in grams at harvest.

Marketable and tuber yield (kg)

At harvesting, the plants harvested from the net area were taken from each plot to determine the marketable seed tuber yield. In this study, marketable tubers included healthy tubers with size categories greater than 25 mm in diameter.

Unmarketable tuber yield (kg)

Diseased, rotten, insect-attacked, deformed tubers and tubers with a diameter less than 25 mm (non-marketable) were weighed and tabulated.

Total tuber yield (mt/ha)

Total tuber yield were recorded as the sum of marketable tuber and unmarketable tuber.

RESULTS AND DISCUSSION

Growth parameter:

The number of plants germinated

The combination of different rates of inorganic fertilizers with various levels of organic manures has a significant on a number of plant germinations shown in Table 1. The germination count was recorded in 30 DAS. The highest number of plants (21) were germinated in the treatment RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha, whereas the lowest number of plants (12.33) were germinated in treatment control. INM can improve seed germination rates by providing plants with the nutrients they need to break dormancy and emerge from the soil. For example, a study in India found that INM with the use of organic manure and inorganic fertilizers increased the germination rate of wheat seeds by 15% compared to the control treatment (Kadu et al., 2013).

Table 1. Effect of integrated nutrient management on the number of planted germinated at Achham, 2023

Treatments	No. of plant germinated
RDF (100:100:60)	15.00^{c}
RDF (75%)+ FYM (20 ton/ha)	17.00^{bc}
RDF (75%)+ Vermicompost (8 ton/ha)	17.00^{bc}

RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	17.00^{bc}
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	18.66^{ab}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	21.00^{a}
Control	12.33^{d}
SEM (±)	0.86
LSD (0.05)	2.65
F-test	***
CV%	8.85
Grand mean	16.85

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Plant height (cm)

The plant height was recorded on various plant growth stages of potato and it represents the growth and vigor of the plant. The application of different organic and inorganic fertilizers had a considerable impact on the height of the plants as shown in table (2). The data indicated significant differences in plant height of potatoes among various treatments. Plant height was recorded at 45, 60, and 75 days after sowing. At 45 days after sowing, the maximum plant height (22.4 cm) was recorded in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by the treatment (RDF @ 75% + FYM @ 2 ton/ha + Zincsulphate @ 20kg/ha). The minimum plant height (16.40) was recorded in control. The maximum plant height (29 cm) was recorded in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) at 60 days after sowing followed by treatment (RDF @ 75%)+FYM @ 2ton/ha)+Zincsulphate @ 20kg/ha), whereas the minimum plant height (23.86 cm) at this stage was recorded in control. At 75 days after sowing, the maximum plant height (39.2 cm) was recorded in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by treatment (RDF @ 75% + FYM @ 2 ton/ha + Zincsulphate @ 20 kg/ha), which is statistically at par with RDF @ 75% + FYM @ 2 ton/ha + sulphur @ 20 kg/ha). The minimum plant height (29.46 cm) was recorded in control. The findings of this experiment are similar to the findings of Gonzalez et al. (2001) who state that it is organic manure and inorganic fertilizer that supply all the required nutrients at the seedling stage increasing measured variables like plant height.

Table 2. Effect of integrated nutrient management on plant height of potato at Achham

Treatments	Plant height at 45 DAS	Plant height at 60 DAS	Plant height at 75 DAS
RDF (100:100:60)	19.66^{bc}	26.06^{c}	33.20^{d}
RDF (75%)+ FYM (20 ton/ha)	18.73^{c}	25.93^{c}	34.26^{cd}
RDF (75%)+ Vermicompost (8 ton/ha)	19.40^{c}	26.06^{c}	35.53^{bc}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	19.60^{bc}	26.46^{bc}	36.06^{b}
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	21.13^{ab}	27.13^{b}	36.46^{b}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	22.40^{a}	29.00^{a}	39.20 ^{a}
Control	16.40^{d}	23.86^{d}	29.46^{e}
SEM (±)	0.51	0.25	0.57
LSD (0.05)	1.59	0.77	1.76
F-test	***	***	***
CV%	4.57	1.65	2.84
Grand mean	19.61	26.36	34.88

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Number of leaves per plant

The number of leaves were significantly influenced by the application of various organic and inorganic fertilizers as suggested by table 3. Number of leaves per plant was recorded at 45, 60 and 75 days after sowing. At 45 days, maximum number of leaves (18.18) was recorded in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) which is followed by the treatment (RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha). The minimum number of leaves (12.61) was recorded in control. At 60 days after sowing, maximum number of leaves (24.2) were recorded in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) which is followed by treatment (RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha) whereas, the minimum number of leaves (19.06) at this stage was recorded in control. At 75 days after sowing the maximum number of leaves (29.2) was recorded in treatment T6 (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20

kg/ha + Zincsulphate @ 20 kg/ha). The minimum number of leaves (24.46) was recorded in control. The maximum number of leaves recorded in treatment T6 might be due to the integrated use of organic manures and inorganic fertilizers that enhanced the plant's nitrogen utilization ability (Raghav et al., 2008).

Table 3. Effect of integrated nutrient management on number of leaves per plant of potato at Achham, 2023

Treatments	No. of leaves at 45 DAS	No. of leaves at 60 DAS	No. of leaves at 75 DAS
RDF (100:100:60)	15.88^{b}	21.44^{c}	26.40^{cd}
RDF (75%)+ FYM (20 ton/ha)	16.66^{b}	21.53^{c}	26.06^{d}
RDF (75%)+ Vermicompost(8 ton/ha)	16.53^{b}	21.53^{c}	26.46^{cd}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	16.60^{b}	21.73^{c}	27.00^{c}
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	17.17^{ab}	23.00^{b}	28.13^{b}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	18.18^{a}	24.20^{a}	29.20^{a}
Control	12.61^{c}	19.06^{d}	24.46^{e}
SEM (±)	0.44	0.23	0.19
LSD (0.05)	1.37	0.73	0.60
F-test	***	***	***
CV%	4.77	1.90	1.26
GrandMean	16.23	21.78	26.81

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Number of stems

Application of organic and inorganic fertilizers at 45, 60 and 75 DAS has a major impact on the number of stems as shown in table 4. At 45 DAS, the maximum number of stems (4.97) were observed in treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by treatment (RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha) which was statistically at par with treatment control. The minimum number of stem were observed in treatment (RDF @ 75% + Vermicompost @ 8ton/ha). At 60 DAS, the maximum number of stem (8.86) was seen in treatment (RDF

@ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by (RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha) . The minimum number of stem (4.53) was observed in control. At 75 DAS, the maximum number of stem (14.26) was observed in treatment (RDF @75% + FYM @2 ton/ha + Sulphur @20 kg/ha + Zincsulphate @ 20 kg/ha) followed by treatment (RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha) which is statistically at par with treatment (RDF @ 75% + FYM @ 2ton/ha + Sulphur @ 20kg/ha). The minimum number of stem (9.33) was observed in control. The result of this experiment was similar to the study conducted in Ethopia which reported that INM provides plants with a more balanced supply of nutrients, which can lead to increased vegetative growth (Mhammed et al., 2018). Other factors that might affect the number of stems include the state in which the tubers are stored, the number of viable sprouts at planting, circumstances for growth and sprout damage at planting (Allen, 1978), and the physiological age of the seed tuber (Iritani, 1968).

Table 4. Effect of integrated nutrient management on the number of stems of potato at Achham, 2023

Treatments	No. of stems at 45 DAS	No. of stems at 60 DAS	No. of stems at 75 DAS
RDF (100:100:60)	2.40^{b}	5.80^{c}	10.93^{c}
RDF (75%)+ FYM (20 ton/ha)	2.73^{b}	6.13^{c}	11.33^{c}
RDF (75%)+ Vermicompost (8 ton/ha)	2.20^{b}	6.13^{c}	11.66^{c}
RDF (75%)+ FYM(2ton/ha)+ Sulphur (20 kg/ha)	2.26^{b}	6.46^{c}	12.73^{b}
RDF (75%)+ FYM(2ton/ha)+ Zincsulphate (20 kg/ha)	4.36^{ab}	7.40^{b}	13.20^{b}
RDF (75%)+FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	4.97^{a}	8.86^{a}	14.26^{a}
Control	2.85^{ab}	4.53^{d}	9.33^{d}
SEM (±)	0.70	0.24	0.2421
LSD (0.05)	2.17	0.74	0.74
F-test	.	***	***
CV%	39.3	6.46	3.51
Grand mean	3.11	6.47	11.92

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Plant Canopy (cm)

The plant canopy observed in 45, 60 and 75 DAS was significantly influenced by the application of various above treatments. At 45 DAS, treatment control had the lowest (28.4 cm) plant canopy while treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) had the highest plant canopy (40.33cm) followed by treatment RDF @ 75% + FYM @ 2ton/ha + Zincsulphate @ 20kg/ha). At 60 DAS the treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) had highest plant canopy (57.8cm) followed by treatment RDF @ 75%+ FYM @ 2 ton/ha + Zincsulphate @ 20 kg/ha) whereas the minimum plant canopy (40.86cm) was observed in treatment RDF (100:100:60). At 75 DAS the treatment (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) had highest plant canopy (69.06 cm) followed by RDF @ 75%+ FYM @ 2 ton/ha + Zincsulphate @ 20 kg/ha. The minimum plant canopy (58.26 cm) was observed in control. The results of this study was similar to the study conducted in Bangladesh that suggested application of 20 kg/ha of zinc sulphate resulted in the highest canopy diameter. Zinc sulphate is a micronutrient that is essential for plant growth. It helps to promote photosynthesis and protein synthesis, which can lead to increased canopy diameter (Rahman et al., 2015).

Table 5. Effect of integrated nutrient management on canopy diameter of potato at Achham, 2023

Treatments	Canopy diameter at 45 DAS	Canopy diameter at 60 DAS	Canopy diameter at 75 DAS
RDF (100:100:60)	33.13^{c}	40.86^{d}	61.06^{d}
RDF (75%)+ FYM (20 ton/ha)	33.93^{c}	47.73^{bcd}	61.86^{d}
RDF (75%)+ Vermicompost (8 ton/ha)	33.73^{c}	48.53^{bcd}	62.86^{cd}
RDF (75%)+FYM (2 ton/ha)+ Sulphur (20 kg/ha)	34.86^{bc}	48.80^{bc}	64.53^{bc}
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	39.00^{ab}	53.00^{ab}	66.53^{b}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	40.33^{a}	57.80^{a}	69.06^{a}
Control T	28.40^{d}	41.93^{cd}	58.26^{e}

SEM (±)	1.52	2.49	0.71
LSD (0.05)	4.69	7.68	2.19
F-test	**	**	***
CV%	7.58	8.92	1.94
Grand Mean	34.77	48.38	63.45

*Note: ** significant at 1% level of significance, *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Yield parameter

Total number of tuber per hill

Analysis of variance for number of total tuber per hill showed significant differences among various fertilizers combination shown in table 6. With the application of T6 (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha), we get maximum number of tubers per plant (8.33) followed by T5. The lowest number of tuber per hill (4.73) was observed in the control. The increased photosynthetic activity and translocation of photosynthate to the root, which may have aided in the initiation of more stolons in potatoes, may be the cause of the increase in average tuber number observed with the combined application of various organic and inorganic fertilizers (Annad and Krishinappa, 1989). According to Ebwongu et al. (2001), tuber number is also influenced by the quantity of stems generated, which in turn depends on the size and diversity of the tuber.

Tuber weight (kg)

The tuber weight were observed highest (0.08 kg) in treatmentT6 (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by T5 and lowest (0.04 kg) was recorded in the control. The increased photosynthetic activity and photosynthetic enzyme translocation to the root, which may aid in the start of additional stolons in potato plants, may be the cause of the rise in average tuber weight observed with the combined application of organic and inorganic fertilizers (Annad and Krishinapp, 1989).

Table 6. Effect of integrated nutrient management on number of tuber per hill and weight per tuber of potato at Achham, 2023

Treatments	No. of tuber per hill	Tuber weight
RDF (100:100:60)	6.20 ^{e}	0.05 ^{d}
RDF (75%)+ FYM (20 ton/ha)	6.66^{de}	0.06^{bcd}
RDF (75%)+ Vermicompost (8 ton/ha)	6.93cd	0.06^{cd}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	7.33^{bc}	0.07^{ab}
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	7.66^{b}	0.07^{bc}
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	8.33^{a}	0.08^{a}
Control	4.73^{f}	0.04^{e}
SEM (±)	0.17	0.0043
LSD (0.05)	0.53	0.01
F-test	***	***
CV%	4.41	11.59
Grand mean	6.83	0.06

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Tuber yield (kg)

Marketable and unmarketable tuber yield

The integration of different rates of both organic and inorganic fertilizers showed significant effect on both marketable and unmarketable tuber yield shown in table 7. The maximum marketable tuber yield (10.24 kg) was recorded in T6 (RDF @ 75% +FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by T5 which is statistically at par with T4 (8.12 kg) whereas the minimum marketable tuber yield (3.4 kg) was recorded in control. The maximum unmarketable tuber yield (1.06 kg) was recorded in control followed by T1. The minimum unmarketable yield (0.29 Kg) was observed in T6. It is obvious that in the treatments which had higher marketable tuber number will have lower unmarketable tuber number, thus the minimum marketable tuber number was obtained in control. The result of this experiment was similar to the study conducted in Bangaladesh which shows organic fertilizers help to slow down the release of nutrients from inorganic fertilizers, which prevent nutrient leaching. Inorganic fertilizers help to

provide plants with the nutrients they need to grow quickly, which can lead to increased marketable yield (Ebwongu et al.,2001).

Table 7. Effect of integrated nutrient management on marketable and unmarketable tuber yield of potato at Achham, 2023

Treatments	Marketable yield (Kg)	Unmarketable yield (Kg)
RDF (100:100:60)	5.77[d]	0.86[b]
RDF (75%)+ FYM (20 ton/ha)	6.72[c]	0.74[bc]
RDF (75%)+ Vermicompost (8 ton/ha)	7.13[c]	0.66[c]
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	8.12[b]	0.60[cd]
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	8.58[b]	0.45de
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	10.24[a]	0.29[e]
Control	3.04[e]	1.06[a]
SEM (±)	0.22	0.0582
LSD (0.05)	0.69	0.1793617
F-test	***	***
CV%	5.53	15.08
Grand mean	7.08	0.66

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

Total tuber yield (mt/ha)

Maximum total tuber yield (28.33 mt/ha) was obtained where we apply T6 (RDF @ 75% + FYM @ 2 ton/ha + Sulphur @ 20 kg/ha + Zincsulphate @ 20 kg/ha) followed by T5 which is followed by T4, T3, T2 and T1. The lowest total tuber yield (14.44 mt/ha) was recorded in the control. Therefore, the maximum tuber yields in these treatments may be due to increases tuber weight, tuber girth and higher proportion of large and medium sized tuber. These result are in conformation with Sood (2007) who observed higher potato tuber yield under integrated use of organic (FYM) and inorganic source. Zinc sulphate is a micronutrient that is essential for cell division. It helps to promote the growth of new cells, which can lead to increased tuber yield. A study conducted in Nepal

found that the application of 10 kg/ha of zinc sulphate resulted in a 10% increase in potato yield (Poudel et al., 2017). Sulphur is a micronutrient that is essential for photosynthesis. It helps to promote the production of chlorophyll, which is necessary for the conversion of light energy into food (Singh et al., 2015). Fuchs et al. (1970) reported that nutrients from mineral fertilizers enhance the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined. Murwira and Kirchman (1993) observed that nutrient use efficiency might be increased through the combination of manure and mineral fertilizer.

Table 8. Effect of integrated nutrient management on marketable and unmarketable tuber yield of potato at Achham, 2023

Treatments	Yield (mt/ha)
RDF (100:100:60)	19.53 [b]
RDF (75%)+ FYM (20 ton/ha)	20.74[b]
RDF (75%)+ Vermicompost (8 ton/ha)	20.92[b]
RDF (75%)+ FYM (2 ton/ha)+ Sulphur (20 kg/ha)	21.94[b]
RDF (75%)+ FYM (2 ton/ha)+ Zincsulphate (20 kg/ha)	23.70[b]
RDF (75%)+FYM (2 ton/ha)+ Sulphur (20 kg/ha)+ Zincsulphate (20 kg/ha)	28.33[a]
Control	14.44[c]
SEM (±)	1.4299
LSD (0.05)	4.40
F-test	***
CV%	11.58
Grand mean	21.37

*Note: *** significant at 0.1% level of significance, SEM – Standard Error of Mean, CV – Coefficient of Variation, LSD – Least Significance Difference*

CONCLUSION

The field experiment carried out during 2023 at Mangalsen municipality, Thatikhand, Achham district brought some important information about effect of integrated nutrient management on growth and yield attributing characters of potato which were significantly affected by different organic and inorganic fertilizers. The maximum plant height was reported in the treatment (RDF @75% + FYM @2 ton/ha + Sulphur @20 kg/ha + Zincsulphate @20 kg/ha) at 45, 60 and 75 DAS and the lowest plant height was

reported in control treatment in all stages. The maximum number of leaves was recorded in the treatment (RDF @ 75%+FYM @ 2ton/ha+Sulphur @ 20kg/ha+Zincsulphate @ 20kg/ha) at 45, 60 and 75 DAS and the minimum number of leaves was recorded in control treatment. Other growth parameters observed in the research as number of stem and plant canopy were reported maximum at final stage of growth i.e. 75 DAS which was followed by the treatment (RDF @75% + FYM @2 ton/ha + Zincsulphate @20kg/ha) and minimum in the control treatment. Similarly, yield attributing characters such as number of tuber per hill, average tuber yield and total yield were also recorded in the treatment (RDF @ 75%+FYM @ 2ton/ha+Sulphur @ 20kg/ha+Zincsulphate @ 20kg/ha) followed by the treatment in all respective yield attributing characters. The results showed that the application of T6 was superior integrated nutrient management compared to other treatments for improving potato production by altering the soil environment for better crop stand and greater yield. Growth attributing character such as high number of plant germinated, higher plant height, more number of leaves and stems and greater canopy diameter were also recorded highest in the treatment T6. Similarly, yield characters such as number of tuber per hill, average tuber yield and total yield were also recorded highest in the treatment T6. Thus based on the results of this study, it is recommended to use the INM treatment (RDF @ 75%+FYM @ 2ton/ha+Sulphur @ 20kg/ha+Zincsulphate @ 20kg/ha) to improve the growth and yield of potato in Achham district.

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