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# Improving Potato Production through non Monetary Agronomic Manoeuvring

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## ABSTRACT

A field experiment was conducted with an objective to improve potato production through non monetary agronomic manoeuvring during the *Zaid* season of 2015-2016 and 2016-2017 at three village's *viz*. Audung, Seru and Namtsering in Tawang district of Arunachal Pradesh. Experiment consist of four inter row spacing and five earthing up treatments. Results revealed that growth, development, yield attributes and tuber yield was greatly influenced by the treatment under investigation. Majority of growth and yield parameters was recorded maximum with the row spacing of 40 and 30 cm inter row spacing. Significantly the highest marketable tuber yield (15.3 t/ha) was produce at 30 cm inter row spacing. Earthing up at 15 days after plant emergence resulted superior performance in most growth and yield parameters. For better potato production 30 cm intr row spacing and earthing up at 15 days after emergence can be used advocated for Tawang district (Arunachal Pradesh).

*KEYWORD*

Inter row spacing, earthing up, growth parameters, tuber yield

## INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most important food crop in the world followed by rice, maize and wheat (Singh *et al*., 2015). It is a staple food crop in some countries and in others it is used as vegetable (Singh and Singh, 2016). Potatoes are an economical food; they provide a source of low cost energy to the human diet (Kharumnuid *et al*., 2018). According to the quantity of production and consumption worldwide, potato is the most important vegetable crop (Singh *et al*., 2015). India grows about 0.83 million hectare of potato with total production of 15.32 million tonnes of tuber giving an average yield of 15.32 t/ha (Anonymous, 2016). In Arunachal Pradesh it is grown over an area of 5165 hectare with total production 47,000 mt and average yield 9.0 t/ha. In Tawang district it is cultivated over an area of 474 ha with total production 5153 mt and the average yield is 10.87 t/ha. The potato productivity of Tawang district is low as compared to average national productivity due to poor agronomic practices, lack of sustainable supply of improved seed material, high cost of seed tubers, disease and pest problem and inadequate storage (Singh and Singh, 2016). The most important constraints of potato production in the study area are lack of information on agronomic practices such as inter row spacing and time of earthing up, since no research has so for been conducted for the area to determine the optimum inter -row spacing and time of earthing up for optimum yield of potato. Any inter row spacing variation could influence biomass accumulation and subsequently tuber number (Singh *et al*., 2015). In the absence of optimal inter row spacing practices could significantly reduce total tuber yield up to 50%. Therefore, optimization of inter row spacing is the one of most important agronomic practices of potato production as it affects the seed cost, plant development and potato tuber yield (Gulluoglu and Agrioglu, 2009). Proper earthing up increases tuber yields by creating favourable conditions for tuber initiation and development and also reduces yield loss (Singh and Singh, 2016.). Therefore, the present study was conducted to determine the effect of inter row spacing and time of earthing up on growth and yield of potato.

## MATERIALS AND METHODS

### Description of the study area

A field experiment was conducted the Zaid season of 2015-2016 and 2016-2017 at three village's viz. Audung, Seru and Namtsering in Tawang district of Arunachal Pradesh. The area falls under humid subtropical climate. The daily temperature of the experimental site between minimum 11$^0$C and maximum 25$^0$C with an average rainfall of 2110 mm. The soil was sandy loam with slightly acidic reaction (pH 5.8), high in organic carbon (0.87), with electrical conductivity 0.25 ds/m and Available Nitrogen (285.0 kg/ha), Available Phosphorous (14.9 kg/ha) and Exchangeable Potassium (213 kg/ha).

### Experimental treatment

Potato variety "Kufri Girdhari" was used for the experiment. Four level of inter row spacing i.e. 10, 20, 30 and 40 cm per row and four time of earthing up: earthing up after 15 days, 30 days and 45 days after emergence of potato and no earthing up as a control treatment.

### Experimental procedure

The application of organic manures particularly farm yard manure or compost is recommended for potato crop. Organic manures not only supply nutrients to the

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crop but also improve physical conditions of soils such as soil texture and its water retention capacity. Apply 20.0 t/ha of well rotten F.Y.M. at the time of land preparation. Potato variety "Kufri Girdhari" was sown in the first week of February @ 20 q/ha at 12 cm depth. The weed control in Potato crop is normally done by manual labour and control of "Late blight" disease by using Dithane M-45 @ 2 gm/litter of water. Earthing up was done uniformly by hilling the soil around the plant up to 20 cm height and 15 cm width according to the time of earthing up given for each treatment except the control.

**Data collection and analysis:**

To evaluate the effect of inter row spacing and earthing up on potato growth and yield, data were collected for growth parameters such as days to flowering, days to maturity, plant height, plant spread, number of main stems, stem diameter and yield parameters such as number of tubers per plant and total tuber yield (Zelalem *et al.*, 2009) from ten randomly selected plants of the two middle rows. The crop was manually harvested in the month of June.

## RESULT AND DISCUSSION

**Effect of inter row spacing and earthing up on growth parameters**

The effect of both inter row spacing and time of earthing up were found significant on all the growth parameters studied including days to 50% flowering and maturity, plant height, spread and stem diameter except main stem number which is only significantly affected by time of earthing up (Table 1 and 2).

**Days to 50% flowering**

The earliest days to 50% flowering was observed at the closer inter row spacing of 10 cm and 20 cm whereas, days to 50% flowering was prolonged in 30 and 40 cm inter row spacing (Table 1). Days to 50% flowering was delayed by about 5 days in the wider inter row spacing as compared to the closest inter row spacing of 10 cm. This could be due to higher competition of plants for resources in the closer inter row spacing that lead the plants to stress and ultimately the plants flower early instead of prolonged vegetative growth. For earthing up, the earliest days to 50 % flowering (59.05) was observed at no earthing up (control) treatment and this was not significantly from potato plant earthed up at 45 days after complete plant emergence. However, flowering was prolonged when potatoes was earthed up at 15 days after complete plant emergence (Table 1). Days to 50% flowering was delayed by about 5 days earthing up after complete plant emergence as compared to the control. This could be due to the fact that absence of earthing up created stress on the plant due to lack of aeration and mechanical barrier of soil colloids during its active growth stage that affected the plant growth and brought early flowering.

**Days to 50% maturity**

The earliest days to 50 % maturity (107.50) was observed at the closer inter row spacing of 10 cm but it was extended (120.50) at the wide inter row spacing of 40 cm (Table 1). Days to 50 % maturity was delayed by 13 days in thewider inter row spacing as compared to the closest inter row spacing of 10 cm. This could be due to the presence of intense inter plant competition at the closer inter row spacing that leads to depletion of the available nutrient and as a result plants stressed and tend to mature earlier. The current finding is in agreement with the work of (Mengistu and Yamooh, 2010) who concluded that closer inter row spacing (increasing planting density) had shortened days to maturity. For earthing up, the earliest days to 50 % maturity (110.05 days) was occurred at the control (no earthing up) treatment but it was extended (116.50 days) at earthing up of 15 days after complete plant emergence (Table 1). Days to 50 % maturity was delayed by 6 days at 15 days earthing up after the complete plant emergence as compared to the no earthing up treatment. This might be due to the reason that earthing up at 15 days after complete plant emergence, matching with the active growth that extended days to maturity.

**Table 1:** Days to 50% flowering and Days to 50% maturity as influenced by inter -row spacing and time of earthing up .

**Table 1:** Days to 50% flowering and Days to 50% maturity as influenced by inter -row spacing and time of earthing up .

| Treatment | Days to 50% Flowering | | | Days to 50% Maturity | | |
|---|---|---|---|---|---|---|
| | Inter row spacing (cm) | | | | | |
| | 2015-16 | 2016-17 | Average | 2015-16 | 2016-17 | Average |
| 10 | 56.90 | 57.10 | 57.00 | 107.40 | 107.60 | 107.50 |
| 20 | 61.25 | 59.75 | 60.50 | 110.23 | 110.83 | 110.53 |
| 30 | 63.15 | 62.35 | 62.75 | 116.60 | 116.90 | 116.75 |
| 40 | 65.40 | 65.90 | 65.65 | 120.20 | 120.80 | 120.50 |
| | Time of Earthing up (Days) | | | | | |
| No Earthing up | 59.04 | 59.06 | 59.05 | 110.07 | 110.03 | 110.05 |
| 15 | 64.00 | 64.50 | 64.25 | 116.45 | 116.55 | 116.50 |
| 30 | 62.08 | 62.02 | 62.05 | 112.36 | 112.76 | 112.56 |
| 45 | 59.70 | 60.00 | 59.85 | 111.80 | 111.70 | 111.75 |

**Plant height**

The highest plant height (64.15 cm) was obtained at the closer inter row spacing of 10 cm and this is not significantly different from the plant height obtained at 20 cm inter row spacing. On the other hand, the shortest plant height (60.0 cm) was observed at 30 and 40 cm inter row spacing (Table 2). This might be due to the presence of higher competition for sunlight among plant grown at the closer inters row spacing.

This is in agreement with the finding of Singh and Singh, 2016, who indicated that plant height was initially similar in all treatments but after 72 days the closely spaced plants become taller. Similarly Law-Ogbomo and Eghaeevba (2009) concluded that closer inter row spacing (higher plant density) resulted in the highest plant height. In case of earthing up the highest plant height (65.50 cm) was obtained at 15 days earthing up after complete plant emergence, whereas the shortest plant height (60.0 cm) was observed at the control (no earthing up) treatment which is at par with 45 days earthing up after complete plant emergence (Table 2). This might be due to the reason that early soil cultivation (earthing up) facilitated the nutrient absorption through enhanced microbial processes and increased soil aeration.

**Plant spread**

The widest plant spread (39.75 cm) was obtained at the wider inter row spacing of 40 cm but the narrowest plant spread (30.20 cm) was recorded at the closer inter row spacing of 10 cm (Table 2). This could be due to the positive effect of wider inter row spacing, where there is minimum competition for resources between plants compared to the closer inter row spacing, in that the photosynthetic efficiency of plants increased and the plants utilize the sufficiently available resources. This result is in conformity with the finding of Singh and Singh, 2016 who reported that closer inter row spacing resulted in poor vegetative growth such as plant spread compared to the wider inter row spacing. It was also indicated that closer inter row spacing resulted in reduced of branches resulting in the narrowest plant spread. Significantly the widest plant spread (39.50 cm) was observed at 15 days earthing up after complete plant emergence but the narrowest plant spread (32.75 cm) was obtained at the central (no Earthing Up) treatment which is similar to the effect of earthing up at 30 and 45 days after complete plant emergence (Table 2). This could be due to the reason that earthing up at 15 days after complete plant emergence, early in the growing season of the potato plant coincided with the proper time of soil workability and optimum soil moisture level. This made the soil porous and aerated and the plants received the advantage of proper growth and development than the plants on the control and lately managed plots.

**Main stem number**

Significantly the highest main stem number (3.25) was recorded at 15 days earthing up after complete plant emergence but the lowest main stem number (3.0) was obtained at 45 days earthing up after complete plant emergence which was at par with no earthing up (control treatment) and earthing up at 30 days after complete plant emergence (Table 2). This might be due to the fact that earthing up, a cultural practice, given to the plant during its active growth stage, enhanced the growth and development of more number of stems.

**Stem diameter**

The largest stem diameter (5.34 cm) was observed at the wider inter row spacing of 40 cm. whereas, the smallest stem diameter (3.15 cm) was found at the narrowest inter row spacing of 10 cm (Table 2). Wider inter row spacing resulted in less competition among plants, availability of resources, high light interception and large quantity of photo assimilate production as well as assimilation and thus increased plant growth and development ultimately increased stem diameter. In line with current finding, Dennis et al. (1994) that increased inter row spacing resulted in increased stem diameter. The largest stem diameter (4.35 cm) was obtained at 15 days earthing up whereas the smallest stem diameter (3.65 cm) was obtained at no earthing up (Table 2). In no earthing up, there could be lower soil aeration and soil colloids restricted plants roots growth but earthing up controlled the weeds and enabled the plants to absorb more nutrients and increased their stem diameter.

**Effect of inter row spacing and earthing up on yield parameters**

The effect of both inter row spacing and time of earthing up were found highly significant on all yield parameters studied including tuber number, total tuber yield and marketable tuber yield except unmarketable tuber yield which is only significantly affected b inter row spacing (Table 3).

**Tuber number**

Significantly the highest number of tubers per plant (5.0) was recorded at the wider inter row spacing of 40 cm. whereas the lowest number of tubers per plant (2.0) was obtained at the

**Table 2:** Plant height and spread, main stem number and diameter affected by inter - row spacing and time of earthing up

| Treatment | Plant height (cm) | | | Plant spread (cm) | | | Main stem (No) | | | Stem diameter (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inter row spacing (cm) | | | | | | | | | | | | |
| | 15-16 | 16-17 | Ave. | 15-16 | 16-17 | Ave. | 15-16 | 16-17 | Ave. | 15-16 | 16-17 | Ave. |
| 10 | 64.05 | 64.25 | 64.15 | 30.05 | 30.35 | 30.20 | 3.30 | 3.10 | 3.20 | 3.10 | 3.20 | 3.15 |
| 20 | 63.20 | 63.34 | 63.27 | 33.40 | 33.10 | 33.25 | 3.17 | 3.21 | 3.19 | 3.28 | 3.36 | 3.32 |
| 30 | 60.10 | 60.40 | 60.25 | 37.50 | 37.04 | 37.27 | 3.16 | 3.20 | 3.18 | 5.08 | 5.12 | 5.10 |
| 40 | 60.00 | 60.20 | 60.10 | 39.80 | 39.70 | 39.75 | 3.19 | 3.23 | 3.21 | 5.39 | 5.29 | 5.34 |
| Time of Earthing up (Days) | | | | | | | | | | | | |
| No Earthing | 59.75 | 60.25 | 60.00 | 32.85 | 32.65 | 32.75 | 3.02 | 3.04 | 3.03 | 3.63 | 3.67 | 3.65 |
| 15 | 65.40 | 65.60 | 65.50 | 39.70 | 39.30 | 39.50 | 3.20 | 3.30 | 3.25 | 4.42 | 4.46 | 4.35 |
| 30 | 63.80 | 63.70 | 63.75 | 35.55 | 35.25 | 35.40 | 3.07 | 3.03 | 3.05 | 4.20 | 4.10 | 4.15 |
| 45 | 60.15 | 60.35 | 60.25 | 34.30 | 34.20 | 34.25 | 3.05 | 2.95 | 3.00 | 3.82 | 3.88 | 3.85 |

closer inter row spacing of 10 cm (Table 3). In the wider inter row spacing there could be minimum competition among plants for a space and resources and also better plant exposure for high radiation interception that increased the photosynthetic efficiency of the plant and finally resulting in increased number of tuber per plant. Similar to the result of the current investigation also reported that maximum number of tubers per plant was obtained in the wider inter row spacing.

In similar experiment (Gulluoglu and Arioglu, 2009) also reported that number of tubers per plant increased at the wider inter row spacing. In case of earthing up, the highest tuber number (4.70) was recorded at 15 days earthing up after complete plant emergence whereas the lowest tuber number (2.50) was obtained at no earthing up, the control treatment which is at par with earthing up at 45 days after complete plant emergence (Table 3). Earthing up at 15 days after complete plant emergence, during the active growth period of the plant created favourable soil conditions for more number of tubers initiation and development that increased tuber number. Tafi *et al.* (2010) also concluded that earthing up of potatoes at 10 cm plant height increased the length of underground stems that ultimately increased tuber number per plant.

**Total tuber yield**

The highest tuber yield per hectare (21.0 t/ha) was obtained at the closer inter row spacing of 10 cm whereas the lowest (18.3 t/ha) was obtained at the wider inter row spacing of 40 cm (Table 3). This is due to the compensation effect of closer inter row spaced plants per hectare than the wider inter row spacing which resulted in higher yield of tubers per plant. Gulluoglu and Arioglu (2009) investigated the effect of inter row spacing on potato yield and ultimately confirmed that potato tuber yield per hectare was decreased in the wide inter row spacing but increased in the closer inter row spacing due to more tubers being harvested in the closer inter row spacing.

The highest tuber yield (21.5 t/ha) was recorded at 15 days earthing up after complete plant emergence whereas the lowest tuber yield (17.5 t/ha) was recorded at the control (no earthing up) treatment which is at par with tuber yield recorded at 45 days earthing up after complete plant emergence (19.0 t/ha) (Table 3). Earthing up at 15 days after plant emergence coincided with the active growth stage of the plant improved the soil conditions for efficient nutrient absorption resulted in increased plant growth and development that ultimately resulted in the highest tuber yield per hectare.

**Marketable tuber yield**

The highest marketable tuber yield (15.3 t/ha) was obtained at the wider inter row spacing of 30 cm whereas the lowest (12.0 t/ha) was obtained at the closer inter row spacing of 10 cm (Table 3). At the wider inter row spacing due to the presence of minimum competition, plants absorbed the sufficiently available resources and intercepted more light. This increased the photosynthetic efficiency for higher potato assimilates production and ultimately resulted in increased more marketable tuber yield. The highest marketable tuber yield (18.82 t/ha) was obtained at the 15 days earthing up whereas the lowest (12.0 t/ha) was obtained at the closer inter row spacing of 10 cm which is at par with 45 days earthing up (15.4 t/ha) (Table 3).

This could be due to earthing up at 15 days after complete plant emergence, during the active growth period of the plant improved the soil conditions for proper root growth and nutrient absorption that facilitate the above ground part for better growth and development ultimately resulted for the better marketable tuber yield.

**Unmarketable tuber yield**

The highest unmarketable tuber yield (9.0 t/ha) was obtained at the closer inter row spacing of 10 cm. However the lowest unmarketable tuber yield (3.4 t/ha) was obtained at the wider inter row spacing of 40 cm (Table 3).

This could be due to the existence of higher computation between plants in closer inter row spaced plants that results more number of under sized tubers that leads to the less quality product. In this experiment unmarketable tuber yield

**Table 3:** Effect on inter -row spacing and earthing up on tuber number/hill, Total tuber yield, marketable tuber yield and unmarketable tuber yield

| Treatment | Tuber No/hill | | | Total tuber yield (t/ha) | | | Marketable tuber Yield (t/ha) | | | Unmarketable tuber Yield (t/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inter row spacing (cm) | | | | | | | | | | | | |
| | 15-16 | 16-17 | Ave. | 15-16 | 16-17 | Ave. | 15-16 | 16-17 | Ave | 15-16 | 16-17 | Ave. |
| 10 | 1.98 | 2.02 | 2.0 | 21.05 | 20.95 | 21.0 | 11.80 | 12.2 | 12.0 | 8.96 | 9.04 | 9.00 |
| 20 | 3.03 | 2.97 | 3.0 | 20.02 | 19.98 | 20.0 | 13.78 | 14.22 | 14.0 | 5.93 | 6.07 | 6.00 |
| 30 | 3.97 | 4.03 | 4.0 | 19.47 | 19.53 | 19.5 | 15.07 | 15.53 | 15.30 | 4.20 | 4.18 | 4.19 |
| 40 | 5.02 | 4.98 | 5.0 | 18.28 | 18.32 | 18.3 | 14.83 | 14.97 | 14.90 | 3.20 | 3.60 | 3.40 |
| Time of Earthing Up (Days) | | | | | | | | | | | | |
| No Earthing UP | 2.63 | 2.37 | 2.50 | 17.45 | 17.54 | 17.5 | 13.98 | 14.22 | 14.10 | 3.50 | 3.30 | 3.40 |
| 15 | 4.68 | 4.72 | 4.70 | 21.10 | 21.90 | 21.5 | 18.87 | 18.77 | 18.82 | 2.69 | 2.67 | 2.68 |
| 30 | 3.87 | 3.73 | 3.80 | 19.89 | 20.11 | 20.0 | 16.95 | 17.05 | 17.00 | 2.98 | 3.02 | 3.00 |
| 45 | 2.92 | 2.88 | 2.90 | 19.05 | 18.95 | 19.0 | 15.24 | 15.56 | 15.40 | 3.73 | 3.47 | 3.60 |

**Table 4:** Effect on inter -row spacing and earthing up on economics of potato

| Treatments | Gross return (Rs/ha) | Net return (Rs/ha) | Benefit : cost ratio |
|---|---|---|---|
| Inter row Spacing (cm) | | | |
| 10 | 2,70,000 .00 | 1,49,500 .00 | 2.0 |
| 20 | 2,70,000 .00 | 1,52,800 .00 | 2.2 |
| 30 | 2 , 71,400.00 | 1,57,400 .00 | 2.3 |
| 40 | 2,57,500 .00 | 1,44,500 .00 | 1.9 |
| Time of Earthing up (days) | | | |
| No Eearthing up | 2,45,500 .00 | 1,30,500 .00 | 2.0 |
| 15 | 3,09,1,00 .00 | 1,79,100.00 | 2.3 |
| 30 | 2,85,000 .00 | 1,55,500.00 | 2.2 |
| 45 | 2,67,000 .00 | 1,39,000.00 | 2.1 |

## CONCLUSION

It can be concluded from this study that the highest total tuber yield (21.0 t/ha) was produced at the closest inter row spacing of 10 cm. significantly highest marketable tuber yield (15.3 t/ha) was obtained at the wide inter row spacing of 30 cm. was assessed by identifying under sized, diseased, deformed and green potato tubers and the most important reason for unmarketability is under sized potato tuber.

**Effect of inter row spacing and earthing up on economics of potato**

The inter -row spacing and time of earthing up had influenced the economics of potato, inter-row spacing on 30 cm. resulted the highest net return and benefit: cost ratio followed by 20 cm., 10 cm. and 40 cm. Time of earthing up at 15 days after complete plant emergence recorded in highest net return and benefit: cost ratio followed by 30 days, 45 days and no Earthing up (Table 4). It can be concluded that optimum inter -row spacing on 30 cm. and earthing up at 15 days after complete plant emergence in Tawang district of Arunachal Pradesh for better net return and benefit: cost ratio.

Similarly the highest total tuber yield (21.5 t/ha) and marketable tuber yield (18.82 t/ha) was produced at the time of earthing up of 15 days after complete plant emergence of Kufri Girdhari potato variety on the sandy loam soil in Tawang district of Arunachal Pradesh.

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