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Effect of different levels of nitrogen and potassium on physiological characters of sweet potato [*Ipomoea batatas* (L.) Lam.] cv. NFSP-1

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Abstract
A field investigation was conducted at College of Agriculture, CAU, Imphal, Manipur, India during session 2019-20. The study consisted of 16 treatment combinations with 4 levels of Nitrogen (0, 35, 50 and 65 kg/ha of N respectively) and 4 levels of Potassium (0, 35, 50, 65 kg/ha of K respectively) with 3 replications in FRBD on variety NFSP-1. Effect of different levels of N and K on different physiological parameters are as follows. Higher level of N and K gave higher Plant Growth Efficiency or PGE (%), Net Assimilation Rate or NAR (g/m^2/day), Crop Growth Rate or CGR (g/m^2/day) and Relative Growth Rate or RGR (g/g/day) but with a declining trend towards maturity stage. As for Harvest Index (HI), maximum dose of N and second highest dose of K gave highest HI. Interaction between N and K showed significant differences between the treatments pertaining to PGE, NAR and HI only.

Keywords: Sweet potato, NFSP-1, nitrogen, potassium, FRBD, physiological characters, plant growth efficiency, net assimilation rate, crop growth rate, relative growth rate, harvest index

1. Introduction
Sweet potato [*Ipomoea batatas* (L.) Lam.] is an important tuber crop grown mostly in tropical and subtropical regions of Asia, the tropical Americas, the Pacific Islands and Papua New Guinea. India and China are the leading sweet potato growing countries in the world.
Sweet potato [*Ipomoea batatas* (L.) Lam.] belongs to the Convolvulaceae family. It is a natural hexaploid (2n=6x=90) with chromosome irregularities are common leading to infertility. It is a morning glory family, the basic chromosome number of which is x=15 in *Ipomoea* species and there are also diploids (2n=2x=30) and tetraploids (2n=4x=60).
Plant physiology is a sub-discipline of botany concerned with the functioning, or physiology, of plants. Closely related fields include plant morphology, plant ecology, phyto-chemistry, cell biology, genetics, biophysics and molecular biology.
The field of plant physiology includes the study of all the internal activities of plant such as those chemical and physical processes associated with life as they occur in plants. This includes study at many levels of scale of size and time. At the smallest scale are molecular interactions of photosynthesis and internal diffusion of water, minerals, and nutrients. At the largest scale are the processes of plant development, seasonality, dormancy, and reproductive control.
Plants require some nutrients in large quantities to survive. Some nutrients are termed macronutrients, where the prefix macro which refers to the quantity needed. Other nutrients, called micronutrients, are required only in trace amounts for plants to remain healthy. Nitrogen and Potassium are two examples of macronutrients.
N is an essential constituent of proteins and is present in many other compounds of great physiological importance in plant metabolism. It is an integral part of chlorophyll which is primary absorber of light energy needed for photosynthesis and also imparts vigorous vegetative growth and dark green colour to plants. It produces early green and delay in maturity to plants. It governs the utilization of K, P and other elements.
The potassium ion (K^+) is actively taken up from soil solution by plant roots. K is essential for photosynthesis, development of chlorophyll and it improves vigour of the plants to enable to withstand adverse climatic conditions. It regulates stomata opening and closing and regulates the movement of ions with in the plants. It also acts in activation of enzymes, enzyme synthesis, and peptide bonds synthesis and regulates H_2O imbalance within the plant.

1.1 Manures and Fertilizers
Manures and fertilizers are important aspects in cultivation of tuber crops because they improve soil structure and soil productivity. Nitrogen, Phosphorus and Potassium are important nutrients for growth, yield and quality of tuber crops.
Different regions of India have varying requirements of fertilizer dose; the quantities of NPK fertilizers to be applied vary with the soil, climate and location in which the crop is grown. The applications of NPK for cultivation of sweet potato per hectare in Bihar, West Bengal and Assam are 40-60 kg ha^{-1} Nitrogen (N), 40 kg ha^{-1} Phosphorus (P) and 40-60 kg ha^{-1} Potassium (K); in Andhra Pradesh it is 60 kg ha^{-1} N, 60 kg ha^{-1} P and 60 kg ha^{-1} K, and in Karnataka it requires 60 kg ha^{-1} N, 60 kg ha^{-1} P and 90 kg ha^{-1} K. (Singh, S.P., 1989).
In Manipur conditions, the quantity of N: P: K has not yet been standardized for maximizing yield and quality of sweet potato. As N and K are limiting factors when it comes to sweet potato cultivation, hence, it would be beneficial to conduct a study to find out the most beneficial dose of Nitrogen and Potassium i.e., N and K requirement for sweet potato cultivation for studying the physiological characters of sweet potato pertaining to the variety NFSP-1. Hence, keeping this view in mind, a research study entitled "Effect of different levels of nitrogen and potassium on physiological characters of sweet potato [*Ipomoea batatas* (L.) Lam.] cv. NFSP-1*"* was conducted with the following objective.

1.2 Objective
To find out the effect of different levels of Nitrogen and Potassium doses on physiological characters of sweet potato.

2. Materials and Methods
The experiment was conducted at College of Agriculture, Central Agricultural University located at Iroisemba, Imphal West, and Manipur, India; during the session 2019-2020. The study was laid out in Factorial Randomized Block Design consisting of 16 treatment combinations with 4 levels of N i.e., 0, 35, 50 and 65 (all in kg ha^{-1}) of N denoted as N_0, N_1, N_2 and N_3 respectively and 4 levels of K i.e., 0, 35, 50, 65 (all in kg ha^{-1}) of K denoted as K_0, K_1, K_2 and K_3 respectively with 3 replications.
Inputs used in the experiment were FYM and inorganic sources of nitrogen, phosphorus and potassium, i.e., Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP) respectively. The quantities of fertilizers applied were as per the treatment requirements. Urea and MOP were applied in two splits; first 50% at the time of planting and the remaining 50% after first weeding and earthing up i.e., at 30 DAP (days after planting) as topdressing. Whole dose of recommended P was applied at planting stage. Vine cuttings of cultivar NFSP-1 were utilized for the experiment which was procured locally. This is a *khariff* season cultivar with multi-lobed leaves and orange-tinged tubers. It matures at about 110-140 days after planting.
Five plants per plot per replication were selected and tagged at random for recording growth characters such leaf area (cm^2) and dry weight of whole plant (g) with effect from 30 days after planting at 20 days interval *viz.* 30, 50, 70 and 90 days after planting and recorded values were used for calculating the physiological parameters such as Plant growth efficiency or PGE (%), Net assimilation rate or NAR ($g/m^2/day$), Crop Growth rate or CGR ($g/m^2/day$) and Relative growth rate or RGR (g/g/day). Data recorded on physiological parameters were subjected to analysis of variance of $p \leq 0.05$.

2.1 Physiological Parameters
2.1.1 Plant Growth Efficiency or PGE (%)

$$PGE = (D_2 - D_1) / D_m \times 100$$

Where
D_m is the maximum dry weight or dry weight at harvest.
D_1 is the Dry weight of plant at Time T_1
D_2 is the Dry weight of plant at Time T_2.

2.1.2 Net assimilation rate or NAR ($g/m^2/day$)
NAR indirectly indicates the rate of net photosynthesis. It is expressed as gram of dry matter produced per square meter of leaf per day. For calculating NAR, leaf area of individual plants had to be used. It was recorded by the formula given by Gregory (1926) [3].

$$NAR = \frac{\text{Log } L_2 - \text{Log } L_1}{L_2 - L_1} \times \frac{W_2 - W_1}{t_2 - t_1}$$

Where,
L_1 and L_2 are total leaf are at time t_1 and t_2 respectively.
W_1 and W_2 are total dry weight at time t_1 and t_2 respectively.

2.1.3 Crop Growth Rate or CGR ($g/m^2/day$)
The CGR indicates at what rate the crop was growing i.e., whether the crop is growing at faster rate or slower rate than normal. It is expressed as gram of dry matter produced per day, given by Gardner *et al.* (2010).

$$CGR = W_2 - W_1 / (t_2 - t_1)$$

Where,
W_1 is the whole plant dry weight/m^2 recorded at time t_1,
W_2 is the whole plant dry weight/m^2 recorded at time t_2,
And, t_1 and t_2 are the interval of time.

2.1.4 Relative growth rate or RGR (g/g/day)
Relative growth rate indicates rate of growth per unit dry matter i.e., it expresses the dry weight increase in time interval in relation to the initial weight. In practical situations, the mean RGR is calculated from measurements at t_1 and t_2. It is expressed as gram of dry matter produced by a gram of existing dry matter per day (Reddy and Reddi, 2008).

$$RGR = \frac{\log W_2 - \log W_1}{t_2 - t_1}$$

Where,
W_1 and W_2 refer to whole plant dry weight on two successive periods at t_1 and t_2.

2.1.5 Harvest index or HI (%)
The harvest index or HI was calculated using the formula given by Yoshida (1981).

$$HI (\%) = \frac{\text{Economical Yield}}{\text{Biological Yield}} \times 100$$

3. Results

The physiological parameters were recorded from 30 days after planting (DAP) as in all of the treatments, sweet potato plants had been completely established at this stage. Measurements of growth characters such leaf area (cm^2) and dry weight of whole plant (g) were taken at an interval of 20 days i.e., at 30 DAP, 50 DAP, 70 DAP and 90 DAP and recorded values were used for calculating the physiological parameters such as Plant growth efficiency or PGE (%), Net assimilation rate or NAR (g/m^2/day), Crop Growth Rate or CGR (g/m^2/day) and Relative Growth Rate or RGR (g/g/day) Data recorded on physiological parameters were subjected to analysis of variance of $p \leq 0.05$. Results of effect of different doses or levels of N and K and the interaction between them on physiological characters of sweet potato are as follows.

3.1 Plant Growth Efficiency or PGE (%)

Plant Growth Efficiency (%) of sweet potato was calculated between time intervals 50-70 DAP and 70-90 DAP. Effects of different doses or levels of N and K on PGE are represented in Table 1 while effect of interaction between N and K (N x K) are represented in Table 2.

3.1.1 Effect of Nitrogen

Different levels of N showed significant difference between the treatments regarding Plant Growth Efficiency (PGE) and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, there was an increase in PGE with an increased dosage of N. Highest PGE was exhibited by a dosage of 65 kg/ha of N i.e., N_3 at 24.39% which was significantly higher than other treatments. Minimum PGE at 50-70 DAP was exhibited by a dosage of 0 kg/ha of N i.e., N_0 at 21.91% which was observed to be at par with N_1 (22.15%) i.e., 35 kg/ha of N and N_2 (22.59%).

Highest PGE at 70-90 DAP was exhibited by a dosage of 65 kg/ha of N i.e., N_3 (14.57%) which was significantly higher compared to other treatments. Minimum PGE at 70-90 DAP was exhibited by N_1 i.e., 35 kg/ha of N at 12.16% which was observed to be statistically at par with N_0 at 12.56%.

3.1.2 Effect of Potassium

Different levels of K also showed significant difference between the treatments regarding Plant Growth Efficiency (PGE) and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, there was an increase in PGE with an increased dosage of K. Highest PGE was exhibited by a dosage of 65 kg/ha of K i.e., K_3 at 24.68% which was at par with N_2 (23.80%) and N_1 (23.77%). Minimum PGE at 50-70 DAP was exhibited by a dosage of 0 kg/ha of K i.e., K_0 (18.79%). Highest PGE at 70-90 DAP was exhibited by a dosage of 65 kg/ha of K i.e., K_3 (16.38%) which was significantly higher compared to other treatments. Minimum PGE at 70-90 DAP was exhibited by K_0 i.e., 0 kg/ha of K at 8.56%.

Table 1: Effect of different levels of N and K on Plant Growth Efficiency (%) of sweet potato tubers.

Treatments	50-70 DAP	70-90 DAP
N_0	21.91	12.56
N_1	22.15	12.16
N_2	22.59	13.68
N_3	24.39	14.57
S.E(d) (±)	0.52	0.35
C.D (0.05)	1.06	0.72
K_0	18.79	8.56
K_1	23.77	13.32
K_2	23.80	14.70
K_3	24.68	16.38
S.E(d) (±)	0.52	0.35
C.D (0.05)	1.06	0.72
General Mean	22.76	13.24

3.1.3 Effect of Interaction

Interaction between the different doses or levels of N and K also showed significant difference between the treatments with a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50 DAP-70 DAP, highest PGE was exhibited by a combination of 0 kg/ha of N and 65 kg/ha of K i.e., N_0 x K_3 (28.11) which was observed to be at par with N_3 x K_3 (26.91%), N_2 x K_2 (26.48%) and N_3 x K_1 (26.24%). Minimum PGE was exhibited by a combination of 0 kg/ha of N and 0 kg/ha of K i.e., N_0 x K_0 at 14.53%.

At 70-90 DAP, maximum PGE was exhibited in a combination of 0 kg/ha of N and 65 kg/ha of K i.e., N_0 x K_3 (18.66%) which was found to be at par with a combination of 65 kg/ha of N and 50 kg/ha of K i.e., N_3 x K_2 (18.16%), N_3 x K_3 (17.66%) and N_2 x K_3 (17.45%). Minimum PGE was exhibited by a combination of N_0 x K_0 (7.61%) i.e., 0 kg/ha of both N and K which was found to be at par with N_1 x K_0 (8.00%) i.e., 35 kg/ha of N and 0 kg/ha of K and N_2 x K_0 (8.80%) i.e., 50 kg/ha of N and 0 kg/ha of K.

Table 2: Effect of interactions between different levels of N and K on plant growth efficiency (%) of sweet potato tubers.

Treatments	50-70 DAP	70-90 DAP
N_0K_0	14.53	7.61
N_0K_1	22.34	11.65
N_0K_2	22.66	12.30
N_0K_3	28.11	18.66
N_1K_0	19.24	8.00
N_1K_1	24.81	16.20
N_1K_2	23.23	12.69
N_1K_3	21.31	11.76
N_2K_0	19.81	8.80
N_2K_1	21.70	12.81
N_2K_2	26.48	15.64
N_2K_3	22.36	17.45
N_3K_0	21.56	9.84
N_3K_1	26.24	12.62
N_3K_2	22.82	18.16
N_3K_3	26.91	17.66
S.E(d) (±)	1.04	0.71
C.D (0.05)	2.11	1.45
General Mean	22.76	13.24

3.2 Net Assimilation Rate or NAR ($g/m^2/day$)
Net Assimilation Rate or NAR ($g/m^2/day$) of sweet potato was calculated between time intervals 50-70 DAP and 70-90 DAP. Effects of different doses or levels of N and K on NAR are represented in Table 3 while effect of interaction between N and K (N x K) are represented in 4.

3.2.1 Effect of Nitrogen
Different levels of N showed significant difference between the treatments regarding NAR and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, there was an increase in NAR with an increased dosage of N. Highest NAR was exhibited by a dosage of 65 kg/ha of N i.e., N_3 at 0.127 $g/m^2/day$ which was significantly higher than other treatments. Minimum NAR at 50-70 DAP was exhibited by a dosage of 0 kg/ha of N i.e., N_0 at 0.111 $g/m^2/day$ which was found to be at par with N_1 and N_2 which were each 0.112 $g/m^2/day$.

Highest NAR at 70-90 DAP was exhibited by a dosage of 65 kg/ha of N i.e., N_3 (0.085 $g/m^2/day$) which was significantly higher compared to other treatments. Minimum NAR at 70-90 DAP was exhibited by N_0 i.e., 0 kg/ha of N at 0.055 $g/m^2/day$.

3.2.2 Effect of Potassium
Different levels of K also showed significant difference between the treatments regarding NAR and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, there was an increase in NAR with an increased dosage of K. Highest NAR was exhibited by a dosage of 65 kg/ha of K i.e., K_3 at 0.131 $g/m^2/day$ which was significantly higher than other treatments. Minimum NAR at 50-70 DAP was exhibited by a dosage of 0 kg/ha of K i.e., K_0 at 0.096 $g/m^2/day$.

Highest NAR at 70-90 DAP was exhibited by a dosage of 65 kg/ha of K i.e., K_3 (0.073 $g/m^2/day$) which was found to be statistically at par with K_1 (0.070 $g/m^2/day$). Minimum NAR at 70-90 DAP was exhibited by K_0 i.e., 0 kg/ha of K at 0.065 $g/m^2/day$ which was found to be statistically at par with K_2 (50 kg/ha of K) which also gave NAR of 0.065 $g/m^2/day$.

Table 3: Effect of different levels of N and K on Net Assimilation Rate ($g/m^2/day$) of sweet potato tubers.

Treatments	50-70 DAP	70-90 DAP
N_0	0.111	0.055
N_1	0.112	0.062
N_2	0.112	0.070
N_3	0.127	0.085
S.E(d) (±)	0.003	0.002
C.D (0.05)	0.005	0.004
K_0	0.096	0.065
K_1	0.115	0.070
K_2	0.120	0.065
K_3	0.131	0.073
S.E(d) (±)	0.003	0.002
C.D (0.05)	0.005	0.004
General Mean	0.115	0.068

3.2.3 Effect of Interaction
Interaction between the different doses or levels of N and K also showed significant difference between the treatments with a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, highest NAR was exhibited by a combination of 65 kg/ha of N and 65 kg/ha of K i.e., N_3 x K_3 (0.138 $g/m^2/day$) which was found to be statistically at par with N_0 x K_3 (0.138 $g/m^2/day$) i.e., 0 kg/ha of N and 65 kg/ha of K, N_3 x K_2 (0.133 $g/m^2/day$) i.e., 65 kg/ha of N and 50 kg/ha of K, N_2 x K_3 (0.133 $g/m^2/day$) i.e., 50 kg/ha of N and 65 kg/ha of K and N_1 x K_2 (0.130 $g/m^2/day$) i.e., 35 kg/ha of N and 50 kg/ha of K.

Minimum NAR at 50 DAP-70 DAP was exhibited by a combination of 0 kg/ha of N and 0 kg/ha of K i.e., N_0 x K_0 at 0.078 $g/m^2/day$.

At 70-90 DAP, maximum NAR was exhibited by a combination of 65 kg/ha of N and 65 kg/ha of K i.e., N_3 x K_3 (0.106 $g/m^2/day$) which was significantly higher compared to other treatments.

Minimum NAR at 70-90 DAP was exhibited by a combination of 35 kg/ha of N and 65 kg/ha of K i.e., N_1 x K_3 (0.045 $g/m^2/day$) which was found to be statistically at par with a combination of 0 kg/ha of N and 65 kg/ha of K i.e., N_0 x K_3 (0.048 $g/m^2/day$), 35 kg/ha of N and 50 kg/ha of K i.e., N_1 x K_2 (0.049 $g/m^2/day$) and 65 kg/ha of N and 0 kg/ha of K i.e., N_3 x K_0 (0.052 $g/m^2/day$).

Table 4: Effect of interaction different levels of N and K on Net Assimilation Rate ($g/m^2/day$) of sweet potato tubers.

Treatments	50-70 DAP	70-90 DAP
N_0K_0	0.078	0.063
N_0K_1	0.123	0.055
N_0K_2	0.104	0.056
N_0K_3	0.138	0.048
N_1K_0	0.095	0.081
N_1K_1	0.108	0.070
N_1K_2	0.130	0.049
N_1K_3	0.114	0.049
N_2K_0	0.100	0.064
N_2K_1	0.104	0.061
N_2K_2	0.112	0.066
N_2K_3	0.133	0.089
N_3K_0	0.113	0.052
N_3K_1	0.123	0.093
N_3K_2	0.133	0.091
N_3K_3	0.138	0.106
S.E(d) (±)	0.005	0.004
C.D (0.05)	0.010	0.009
General Mean	0.115	0.068

3.3 Crop Growth Rate or CGR ($g/m^2/day$)
Crop Growth Rate or CGR ($g/m^2/day$) was calculated between time intervals 50-70 DAP and 70-90 DAP. Effects of different doses or levels of N, K and interaction of N and K on CGR are represented in Table 5.

3.3.1 Effect of nitrogen
Different levels of N showed significant difference between the treatments regarding Crop Growth Rate (CGR) and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50-70 DAP, there was an increase in CGR with an increased dosage of N. Highest CGR was exhibited by a dosage of 65 kg/ha of N i.e., N_3 at 24.56 $g/m^2/day$ which was significantly higher than other treatments. Minimum CGR at 50-70 DAP was exhibited by a dosage of 0 kg/ha of N i.e., N_0 at 19.04 $g/m^2/day$ which was found to be statistically at par with 35 kg/ha of N i.e., N_1 (19.55 $g/m^2/day$) and 50 kg/ha of N i.e., N_2 (21.30 $g/m^2/day$).

At 70-90 DAP, highest CGR was exhibited by N_3 (15.24 $g/m^2/day$). However, there was no significant difference between the levels of N regarding CGR at 70-90 DAP.

3.3.2 Effect of potassium
Different levels of K also showed significant difference between the treatments regarding Crop Growth Rate (CGR) and showed a decreasing trend from 50-70 DAP to 70-90 DAP.

At 50 DAP-70 DAP, there was an increase in CGR with an increased dosage of K. Highest CGR was exhibited by a dosage of 65 kg/ha of K i.e., K_3 at 22.77 g/m^2/day which was at par with 50 Kg/ha of K i.e., K_2 (22.12 g/m^2/day) and 35 kg/ha of K i.e., K_1 (21.55 g/m^2/day). Minimum CGR at 50 DAP-70 DAP was exhibited by a dosage of 0 kg/ha of K i.e., K_0 at 18.01 g/m^2/day.

At 70-90 DAP, highest CGR was exhibited by K_1 (12.73 g/m^2/day). However, there was no significant difference between the levels of K.

3.3.3 Effect of interaction
Interaction between the different levels of N and K did not exhibit any significant differences between the treatments regarding Crop Growth Rate at both intervals i.e., at 50-70 DAP and 70-90 DAP.

Table 5: Effect of different levels of N and K and their interaction on crop growth rate (g/m^2/day) of sweet potato tubers

Treatments	50-70 DAP	70-90 DAP
N_0	19.04	10.10
N_1	19.55	11.22
N_2	21.30	12.80
N_3	24.56	15.24
S.E(d) (±)	1.56	2.27
C.D (0.05)	3.180	(NS)
K_0	18.01	11.85
K_1	21.55	12.73
K_2	22.12	12.33
K_3	22.77	12.45
S.E(d) (±)	1.56	2.27
C.D (0.05)	3.18	(NS)
Interaction (N x K)		
S.E(d) (±)	3.11	4.55
C.D (0.05)	(NS)	(NS)
General Mean	21.11	12.34

3.4 Relative Growth Rate or RGR (g/g/day)
The Relative Growth Rate or RGR (g/g/day) was calculated between time intervals 50-70 DAP and 70-90 DAP and data is represented in Table 6.

3.4.1 Effect of nitrogen
Different levels of N did not exhibit any significant difference between the treatments in relation to relative growth rate at both intervals i.e., at 50-70 DAP and 70-90-DAP.

3.4.2 Effect of potassium
Different levels of K also did not exhibit any significant difference between the treatments in relation to relative growth rate at both intervals i.e., at 50-70 DAP and 70-90-DAP.

3.4.3 Effect of interaction
Interaction between the different levels of N and K did not exhibit any significant differences between the treatments regarding RGR at both intervals i.e., at 50-70 DAP and 70-90 DAP.

Table 6: Effect of different levels of N, K and N x K on relative growth rate (g/g/day) of sweet potato tubers.

Treatments	50-70 DAP	70-90 DAP
N_0	0.015	0.005
N_1	0.015	0.005
N_2	0.015	0.006
N_3	0.016	0.007
S.E(d) (±)	0.001	0.001
C.D (0.05)	(NS)	(NS)
K_0	0.016	0.006
K_1	0.015	0.006
K_2	0.015	0.006
K_3	0.016	0.005
S.E(d) (±)	0.001	0.001
C.D (0.05)	(NS)	(NS)
Interaction (N x K)		
S.E(d) (±)	0.001	0.003
C.D (0.05)	(NS)	(NS)
General Mean	0.02	0.01

3.5 Harvest index (%)
The data on Harvest Index (%) are represented in Table 7 and represented in Table 8 for their interaction (N x K).

3.5.1 Effect of nitrogen
Different levels of N showed significant difference between the treatments in relation to harvest index. Application of 65 kg/ha of N i.e., N_3 gave maximum value of harvest index at 34.31% which was significantly higher compared to other treatments. Minimum harvest index was observed in an application of 50 Kg/ha of N i.e., N_2 at 21.38%.

3.5.2 Effect of potassium
Different levels of K also showed significant difference between the treatments in relation to harvest index. Maximum harvest index was observed in an application of 50 kg/ha of K i.e., K_2 at 34.05% which was significantly higher compared to other treatments. Minimum harvest index was observed in an application of 35 kg/ha of K i.e., K_1 at 22.68%.

Table 7: Effect of different levels of N and K on Harvest Index (%).

Treatments	Harvest Index (%)
N_0	29.99
N_1	28.77
N_2	21.38
N_3	34.31
S.E(d) (±)	0.42
C.D (0.05)	0.85
K_0	28.11
K_1	22.68
K_2	34.05
K_3	29.61
S.E(d) (±)	0.42
C.D (0.05)	0.85
General Mean	28.61

3.5.3 Effect of interaction
There was significant difference between the treatments for harvest index due to interaction of N and K. Maximum harvest index was observed by a combination of 65 kg/ha of N and 65 kg/ha of K i.e., N_3 x K_3 at 48.58% which was higher and significant compared to other treatments. Minimum harvest index was exhibited by the interaction of N_3 x K_1 i.e., application of 65 kg/ha of N and 35 kg/ha of K at 15.79%.

Table 8: Effect of interaction different levels of N and K on Harvest Index (%).

Treatments	Harvest Index (%)
N_0K_0	29.68
N_0K_1	20.35
N_0K_2	43.06
N_0K_3	26.88
N_1K_0	25.91
N_1K_1	31.18
N_1K_2	37.01
N_1K_3	20.98
N_2K_0	20.56
N_2K_1	23.40
N_2K_2	19.57
N_2K_3	22.00
N_3K_0	36.30
N_3K_1	15.79
N_3K_2	36.57
N_3K_3	48.58
S.E(d) (±)	0.83
C.D (0.05)	1.70
General Mean	28.61

4. Discussions
Discussions on results due to effect of different doses or levels of N and K and their interaction on physiological parameters of sweet potato are discussed as follows.

4.1 Plant Growth Efficiency or PGE (%).
4.1.1 Effect of Nitrogen
Different levels of N showed significant difference between the treatments regarding Plant Growth Efficiency (PGE) with a declining trend throughout the growing period. This may be because of the fact that leaf area development has a greater influence on yield than does NAR. However, the relative importance of N, and hence leaf area development, on sweet potato yield will depend on the fertility of soil at the site.

4.1.2 Effect of Potassium
Different levels of K also showed significant difference between the treatments regarding PGE with a declining trend throughout the growing period. The indication is that K fertilizer increases tuber yield by increasing the proportion of dry matter diverted to the underground tubers rather than any influence on photosynthesis capacity, and its influence on photosynthetic efficiency is not known.

4.1.3 Effect of Interaction
Interaction between the different doses or levels of N and K also showed significant difference between the treatments with a decreasing trend. At harvest, highest PGE was exhibited by a combination of N_0 x K_3 i.e. combination of lowest level of N and highest level of K. This may be due to the positive influence of K in photosynthetic activity of the plant as well as in increasing tuber yield by increasing the proportion of dry matter diverted to the tubers.

4.2 Net Assimilation Rate or NAR ($g/m^2/day$)
4.2.1 Effect of Nitrogen
Different levels of N showed significant difference between the treatments regarding NAR with a declining trend throughout the growing period. This may be possibly due to the fact that NAR exhibits a behavior previously noted in tomato by César *et al.* (2016) [1] i.e., initially increases and then decreases with plant age in the early phenological stages, the leaf area is constantly increasing with the development of new leaves which are more exposed to radiation and are more efficient at capturing CO_2 consequently, the production rate of photo-assimilates increases. As time passes, the amount of foliage increases, and thus, the outer leaves shade the inner leaves, decreasing the photosynthetic activity of the shaded leaves.

4.2.2 Effect of Potassium
Different levels of K also showed significant difference between the treatments regarding NAR with a declining trend throughout the growing period. The indication is that K fertilizer in increasing tuber yield by increasing the proportion of dry matter diverted to the tubers rather than any influence on photosynthetic capacity and as the plant gets older, NAR decreases due to leaves getting older and their shadows on each other and decrease of active photosynthesis area. When all leaves are exposed to complete sunlight, NAR is maximized. This result is in accordance with findings made by Motaghi and Nejad (2014) [5] in cowpea.

4.2.3 Effect of Interaction
Interaction between the different levels of N and K also showed significant difference between the treatments with a decreasing trend. At harvest, highest NAR was exhibited by a combination of N_3 x K_3 i.e. combination of highest level of N and K. This may be due to the positive influence of N in photosynthetic activity of the plant as well as the positive impact of K fertilizer in increasing tuber yield by increasing the proportion of dry matter diverted to the tubers.

4.3 Crop Growth Rate ($g/m^2/day$)
4.3.1 Effect of Nitrogen
Different levels of N showed significant difference between the treatments regarding Crop Growth Rate (CGR) and showed a decreasing trend from 50-70 DAP up to maturity. Decrease in CGR with plant age may be attributed to stoppage of vegetative growth, loss of leaves, and senescence. This result is in accordance with observations made by César *et al.* (2016) [1] in tomato.

4.3.2 Effect of Potassium
Different levels of K also showed significant difference between the treatments regarding Crop Growth Rate (CGR) and showed a decreasing trend from 50-70 DAP to maturity. This trend is because at the beginning of growth season there is gradual increase of absorbing solar radiation along with the increase of green cover percentage and hence the increase of dry matter accumulation in plants. The decrease of CGR at final stages could be due to decrease of plant dry matter because of loss of leaves which have fallen. Generally, CGR depends on canopy photosynthesis per area unit of land. This observation was also made by Motaghi and Nejad (2014) [5] in cowpea and César *et al.* (2016) [1] in tomato.

4.3.3 Effect of Interaction
Interaction between the different doses or levels of N and K did not exhibit any significant differences between the treatments regarding Crop Growth Rate at both intervals i.e. at 50-70 DAP and 70-90 DAP.

4.4 Relative Growth Rate (g/g/day)
4.4.1 Effect of Nitrogen
Even though there was no significant difference between the different levels of N, RGR was more at earlier stage i.e. at 50-70 DAP than at later stage i.e., at 70-90 DAP. RGR was high at the beginning of the crop cycle and then gradually decreases towards the end of the cycle, coinciding with the onset of leaf senescence and shading of lower leaves. This result is in accordance with results obtained by César *et al.* (2016) [1] in tomato.

4.4.2 Effect of Potassium
Although there was no significant difference between the different doses or levels of K, RGR was higher at earlier stage i.e. at 50-70 DAP than at later stage i.e., at 70-90 DAP. The decrease in RGR may be because as the time passes, plant weight increases and consequently the number of dead tissues or tissues which are quite mature and have no role in production will increase. Or we can say that at the beginning of growth, all plant parts and cells have some role in production and are much greater in volume as compared to dead tissues or cells but dead cells and tissues that have no role in production will increase over a period of time and hence lead to a decreasing RGR over time. This is in line with observations made by Motaghi and Nejad (2014) [5] in cowpea.

4.4.3 Effect of Interaction
Interaction between the different doses or levels of N and K did not exhibit any significant differences between the treatments regarding Relative Growth Rate at both intervals i.e. at 50-70 DAP and 70-90 DAP.

4.5 Harvest Index or HI (%)
4.5.1 Effect of Nitrogen
Different doses or levels of N showed significant difference between the treatments regarding harvest index. This may be because of the effect of N in enhancing photosynthetic activity, leading to enhanced vigour of plant thus improving production of assimilates and their subsequent translocation to tubers leading to improved tuber development and growth. Towards maturity, there is stoppage of vegetative growth, loss of leaves, and senescence of the aerial parts leaving behind bigger and developed tubers which give rise to higher harvest index. Similar observation was made by Kavvadias *et al.* (2012) [4] in potato.
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4.5.2 Effect of Potassium
Different levels of K also showed significant difference between the treatments regarding harvest index. This increase in harvest index with the increase in potash level might be due to more partitioning of assimilates toward sink. More harvest index was noted with higher potash applied. This is in accordance with the result obtained by Sadiq *et al*. (2017) [7] in maize.

4.5.3 Effect of Interaction
There was significant difference between the treatments for harvest index (HI) due to interaction of N and K. Highest HI was exhibited by a combination of N_3 x K_3 i.e. combination of highest level of N and K. This may be because of the combined effect of N and K in improving the plant vigour which leads to an increase in number of cells along with cell enlargement and in improving the quantitative and qualitative characteristics of sweet potato. They also lead to the increase in net assimilation rate and dry matter accumulation which in turn improves weight of tubers. Towards maturity, there is stoppage of vegetative growth, loss of leaves, and senescence of the aerial parts leaving behind bigger and developed tubers which give rise to higher harvest index.

5. Conclusions
Physiological parameters were maximum at 65 kg/ha of N (N_3) and 65 kg/ha of K (K_3) higher doses or levels of N and K also gave higher value of Plant Growth Efficiency (PGE), Net Assimilation Rate (NAR), Crop Growth Rate (CGR) with a decreasing trend from 50-70 DAP to 70-90 DAP.
Harvest Index (HI) on the other hand was maximum with an application of 65 kg/ha of N i.e., N_3 and 50 kg/ha of K i.e., K_2.
Interaction between different levels on N and K showed significant effect on PGE and NAR at 70-90 DAP and also in Harvest Index in collaboration with 0 kg/ha of N and 65 kg/ha of K (N_0 x K_3) gave highest value of PGE with 18.66%, a combination of 65 kg/ha of N and 65 kg/ha of K (N_3 x K_3) gave highest value of NAR (0.106 g/m^2/day) and a combination of 65 kg/ha of N and 65 kg/ha of K (N_3 x K_3) gave highest value of Harvest Index at 48.58%. The different interactions between different doses or levels of N and K however did not show significant differences between the treatments for CGR.
Neither different doses of N and K nor their interaction showed any significant differences between the treatments in relation to Relative Growth Rate (RGR).
Based on the current research findings, it can be concluded that different levels of nitrogen and potassium influenced the physiological characters of sweet potato and it can be inferred that 65 kg/ha of N i.e., N_3 and 65 kg/ha of K i.e., K_3 were better in increasing the said characters.

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