ISSN (Online): 2091-2609
DOI Prefix: 10.3126/ijasbt
International Journal of Applied Sciences and Biotechnology (IJASBT)

Research Article

Effect of Planting Geometry on Growth of Rice Varieties

Mohan Mahato[1*] and Bishnu Bilas Adhikari[2]

[1]Institute of Agriculture and Animal Science, Kirtipur, Nepal
[2]Institute of Agriculture and Animal Science, Lamjung, Nepal

Abstract

A field experiment was conducted under humid subtropical agro-climatic condition of Nepal during rainy season of 2014. The experiment was laid out in to two factor Randomized Complete Block Design with three replications consisting three drought tolerant rice varieties (Sukhadhan-4, Sukhadhan-5 and Radha-4) and four planting geometry (15 cm × 10 cm, 15 cm × 15 cm, 20 cm × 15 cm and 20 cm × 20 cm). The results revealed that the highest plant height and maximum leaf area index was recorded in planting geometry 15 cm × 10 cm in all growth stages. Whereas, planting geometry 20 cm × 15 cm produced the maximum number of tiller m^{-2} in all growth stage. While planting geometry 20 cm × 15 cm and 20 cm × 20 cm produced statistically similar crop growth rate and dry matter accumulation in all stage of growth. Regarding the varieties, Sukhadhan-4 showed highest plant height up to 75 DAT and plant height was statistically similar to Radha - 4 in 60 and 75 DAT. But maximum number of tiller m^{-2}, leaf area index, crop growth rate and dry matter accumulation were recorded in Sukhadhan – 5 varieties.

Keywords: Drought tolerant rice; plant growth; planting geometry

Introduction

Rice (*Oryza sativa* L.) is one of the important staple foods in the world and account for 20 % calorie consumed worldwide (Jones and Sheats 2016). Approximately 163.2 million hectare area is covered with rice all over the world with an annual production of 719.7 million tones (FAOSTAT, 2013). It is one of the most important cereal crops of Nepalese agriculture and economy. It is grown in all agro-ecological zones from Terai plains (59 m at Musaharnia of Dhanusa district) to high hills up to 3050 masl (Chhumchure in Jumla district) including valleys and foot hills of Nepal (NARC, 2007; Sapkota *et al.*, 2010). It is grown in about 1.48 million ha with the production of 5.04 million tons and productivity is 3.39 ton ha^{-1} (MOAD, 2014). About 21% (3.2 million hectares) of the total land area of Nepal is used for cultivation where the major crops are rice (45%), maize (20%), wheat (18%), millet (5%) and potatoes (3%), followed by sugarcane, jute, cotton, tea, barley, legumes, vegetables and fruits (Gautam, 2008).

The magnitude of the annual monsoon strongly influences the production of rice in Nepal .The projected climate changes also have considerable impact on agricultural production. Climate-related changes like rainfall pattern, temperature, floods, landslides, soil erosion has been observed (IPCC, 2007). It is estimated that the average temperature in Nepal is rising by 0.5°C per decade (Lama

Article may be cited as:
M. Mahato and B.B. Adhikari (2017) Int. J. Appl. Sci. Biotechnol. Vol 5(4): 423-429. DOI: 10.3126/ijasbt.v5i4.18041

[1]***Corresponding author**
Mohan Mahato,
Institute of Agriculture and Animal Science, Kirtipur, Nepal
Email: mahatomohan@yahoo.com

and Devkota, 2009). The increased temperature with variable rainfall condition create periodic drought in rice growing season and sometime even changes cultivated land in to barren land. The uneven and intermittent distribution of rainfall and shortage of water makes the drought varieties more important (Luo and Zhang, 2001). Drought stress during the vegetative growth period, anthesis and terminal stages of rice cultivation cause sterility in spikelet, which ultimately decreases the yield (Kamoshita *et al*, 2004).

Planting geometry of a crop affects the interception of solar radiation, crop canopy coverage, dry matter accumulation and crop growth rate (Anwar *et al.,* 2011). The closer planting geometry causes competition among plants for light, water, and nutrients which consequently slow down growth as well as the grain yield. Optimum planting geometry ensures the proper growth of aerial as well as underground plant parts by efficient utilization of solar radiation, nutrients and water (Miah *et al.*, 1990). Similarly, the tillering habit and formation of spikelets per panicle also influenced by the planting geometry, which is responsible for the yield of rice per unit area. So the planting geometry and plant spacing should be optimized by keeping in mind different aspects of cropping management techniques. Hence, this study aim was carried out to investigate the influence of different planting geometry on growth of drought tolerant rice varieties.

Materials and Methods

The experiment was conducted in Narayani VDC, ward No. 7 of Nawalparasi district during May to November, 2014. Geographically, it is located at 27˚35’’N Latitude and 84˚2’ E Longitudes at the elevation of 254 m asl. The average monthly minimum and maximum temperature were 20.43˚C and 35.87˚C respectively and the maximum rainfall was observed in the month of August (735 mm). The meteorological data for the growing season of crop during 2014 is presented in Table 1. Soil analysis results show that (Table 2), the soil was silt loam, pH 6.67 and low in organic matter (2.1%). The experiment consist of three drought tolerant rice varieties viz. Sukhadhan-4, Sukhadhan-5 and Radha-4 and four planting geometry viz. 15 cm × 10 cm, 15 cm × 15 cm, 20 cm × 15 cm and 20 cm × 20 cm.

Table 1: meteorological data during crop growing season 2014

Months	**Rain fall (mm)**	**Avg. maximum temperature (ºC)**	**Avg. minimum temperature (ºC)**
June	510.80	35.87	25.76
July	652.60	33.75	25.61
August	735.30	33.40	25.24
September	248.00	33.59	24.32
October	122.00	31.19	20.43

Source: Department of Hydrology and meteorological station, 2014

Table 2: Physico-chemical properties of the soil of the experimental site (2014)

S. N.	Properties	Content	Category
1	**Physical properties**		
	Sand (%)	21.6	
	Silt (%)	58.80	
	Clay (%)	19.60	
	Soil texture		Silt loam
2	**Chemical properties**		
	pH (1:2)	6.67	Slightly Acidic
	Total Nitrogen (%)	0.10	Medium
	Available Phosphorus (P_2O_5 Kg ha^{-1})	45	Medium
	Available Potassium (K_2O Kg ha^{-1})	190.78	Medium
	Organic matter (%)	2.1	Low

The experiment was laid out in randomized complete block design (RCBD) consisting three replication. Each replication consist 12 plots and the unit plot was 9 m^2 (3 m × 3 m) with the total experimental area of 467.5 m^2. The individual plots and replication were separated by 0.5 m. Dry nursery bed was prepared for raising the seedlings and 20 days old seedlings were transplanted in puddled field in 15 cm × 10 cm, 15 cm × 15 cm, 20 cm × 15 cm and 20 cm × 20 cm planting geometry, each hill consisting single seedling. Fertilizer dose of 60:30:20 kg NPK ha^{-1} was applied from urea (46%N), DAP (18% N and 46% P_2O_5) and MOP (60% K_2O). Half dose of Nitrogen and full dose of P and K were applied before final land preparation as basal dose and remaining dose of N was applied at panicle initiation stage. In order to create drought condition no irrigation was done and grows under natural condition.

After 30 days of transplanting different biometrical observations plant height, leaf area index, number of tiller m^{-2}, dry matter accumulation were observed. For plant height, ten hills were selected from the 6^{th} and 10^{th} row of each plot and tagged it for taking plant height in different phase of the crop. The height of each tagged plants was measured at 15 days interval till full maturity stage. Plant height was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of the panicle after heading. The mean height of ten plants is expressed as plant height of each plot. Similarly, Leaf area was measured from the two hills of the destructive sampling row of each plot at 15 days interval. The leaves were detached and the length (l) is measured from the base of leaf to its tips and breadth (b) is measured after dividing equal parts of leaf into three parts from base to tips and measured b_1, b_2, and b_3 manually by using ordinary scale. The mean breadth is calculated and leaf area is calculated by using following formula given by Palaniswamy and Gomez (1974).

$$\text{Leaf area} = \text{K} \ (\text{L} \times \text{W})$$

Where, L is length of leaf, W is the mean width of leaf and K is correction factor (CF) and the value is 0.73 for dry season and 0.75 for wet season.

The leaf area is obtained by using CF and finally Leaf Area Index (LAI) is calculated by using the following formula,

$$\text{LAI} = \frac{\text{Leaf area (cm2)}}{\text{Ground covered area (cm2)}}$$

For dry matter calculation plants of two hills were randomly taken from the destructive sampling rows of each plot from 30 DAT and analysis was continued up to harvesting at 15 day interval. Total above ground portion excluding roots were taken for growth analysis. Dry matter accumulation was determined by drying plant biomass at a temperature of 70° C for 72 hours in hot oven and used for the calculation of crop growth rate. The dry matter accumulation of crop per unit land area of a crop per unit time is referred as crop growth rate. It is expressed as g m^{-2} d^{-1}, g m^{-2} $week^{-1}$ or kg ha^{-1} $week^{-1}$. CGR values of plant above ground biomass from two hills were taken from destructive sampling rows from 30 DAT till harvesting at 15 day interval. CGR values of plant during the sampling intervals are calculated by using the formulae of Brown, 1984.

$$\text{CGR} = \frac{\text{W2} - \text{W1}}{\text{t2} - \text{t1}} \times \frac{1}{\text{A}}$$

Where, W_1 & W_2 are total dry weights of crops over a sampling area, A, at times t_1 and t_2 days after transplanting.

Collected data were analyzed statistically using R- program with Agricola, Least Significant Difference (LSD) and Duncan Multiple range Test (DMRT), as mean separation technique was applied to identify the most efficient treatment (Gomez and Gomez, 1984).

Result and Discussion

Effect on Plant Height

Planting geometry and varieties both significantly ($p<0.01$) affected the plant height in different stage of crop (30, 45, 60 and 75 DAT) (Table 3). The mean plant height observed (58.5 cm) at 30 DAT and was increasing in trend up to reproductive stage. The rapid increase of height was found from 30 - 60 DAT and was less after 60 DAT up to harvest because of accumulation of photosynthetic at reproductive parts of the plant.

Statistically the tallest plant height (61.1 cm) was recorded in closer spacing (15 cm × 10 cm) at 30 DAT and shortest height (57 cm) was recorded in wider spacing (20 cm × 20 cm) at same observation. Mean height of 20 cm × 20 cm spacing (57 cm) had statistically similar with the 20 cm × 15 cm planting geometry (57.3 cm) at 30 DAT. Similarly, at 45 DAT, significantly higher plants height was recorded in 15 cm × 10 cm planting geometry (84 cm) in comparison with 20 cm × 15 cm (77.6 cm), 15 cm × 15 cm (80.7 cm) and 20 cm × 20 cm (76cm). At 60 DAT, significantly tallest plant was recorded in 15 cm × 10 cm plant spacing (101.3 cm) and was at par with 15 cm × 15 cm plant spacing (98.7 cm) whereas the plant height at 20 cm × 15 cm (96.1 cm) and 20 cm × 20 cm (95.8 cm) recorded statistically same height. In addition, at 75 DAT plant spacing 15 cm × 10 cm (109.5 cm) recorded the tallest plant height, which was statistically similar with the 15 cm × 15 cm (107.7 cm) in comparison with 20 cm × 15 cm spacing (104.2 cm) and 20 cm × 20 cm (104.2 cm). The tallest plant height was recorded in closer plant spacing, which might be due to inter-competition among the plants for the interception of maximum solar radiation. To get more radiation, plants grow faster and get more height. Similar, result was reported by M. H. Shah *et al.*, (1991) and H. Om *et al.*, (1993), who reported that the plant height is significantly affected by the different planting geometry and found maximum plant height in closer plant spacing. These results are also accordance with Bezbaruha *et al.*, (2011) and Rasool *et al.*, (2013), who reported that closer plant spacing, produced tallest plant height than wider plant spacing in rice.

Table 3: Effect of different planting geometry on plant height at different time interval of DTR varieties in Narayani VDC, Nawalparasi, Nepal during 2014.

Treatments	Plant height (cm)			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
Varieties (A):				
Radha-4	59.4^{b}	80.8^{b}	99^{a}	107.2^{a}
Sukhadhan-5	55.0^{c}	74.1^{c}	94.6^{b}	103.2^{b}
Sukhadhan-4	61.1^{a}	83.8^{a}	100.3^{a}	108.7^{a}
LSD	**1.46**	**2.94**	**3.85**	**2.51**
SEm±	**0.49**	**1.00**	**1.04**	**0.85**
Spacing (B):				
15 cm × 10 cm	61.1^{a}	84^{a}	101.3^{a}	109.5^{a}
15 cm × 15 cm	58.7^{b}	80.7^{ab}	98.7^{ab}	107.7^{a}
20 cm × 15 cm	57.3^{c}	77.6^{bc}	96.1^{b}	104.2^{b}
20 cm × 20 cm	57^{c}	75.9^{c}	95.8^{b}	104.2^{b}
LSD	**1.68**	**3.40**	**3.52**	**2.90**
SEm±	**0.58**	**1.16**	**1.20**	**0.98**
CV%	**2.95**	**4.37**	**3.68**	**2.78**
Grand mean	**58.48**	**79.54**	**97.96**	**106.38**

Regarding the effect of height on different varieties, statistically plant height was significantly differing among each other. At 30 DAT, Sukhadhan-4 recorded the highest plant height (61 cm) in comparison to Radha-4 (59.4 cm) and Sukhadhan-5 (55 cm). Similar trend was observed at 45 DAT also. At 60 DAT, Sukhadhan-4 (100.3 cm) recorded significantly the tallest plant height which was statistically similar with Radha-4 (99.0 cm) followed by Sukhadhan-5 (94.6 cm). Similar, trend was observed at 75 DAT also.

Effect on Number of Tiller m-2

The number of tiller per square was significantly ($p<0.01$) influenced by both planting geometry and varieties (Table 4) at various stages. At 30 DAT significantly, highest number of tiller per square meter was recorded in planting geometry 20 cm × 15 cm (349) followed by plant spacing 20 cm × 20 cm (317). Maximum number of tiller was recorded at 45 DAT, it was due to the favorable and juvenile condition of rice plant to produce the more tillers. Then after that the number of tiller per hill was decreased at 60 DAT and 75 DAT, due to tiller mortality. At 45 DAT the plant spacing 20 cm × 15 cm produced the maximum number of tiller m^{-2} (397) and minimum number of tiller m^{-2} was recorded in the closer spacing 15 cm × 10 cm (327). Similar trend of tiller production was recorded in 60 DAT and 75 DAT. The number of tiller per square meter was decreased with the closer spacing, because of competition in utilization of available nutrient, more interception of solar radiation and less inter-plant competition in wider spacing. This result was also in line with Garcia *et al.;* (1992), Rodreguze and Ingram (1991); Mohammad *et al.*, (2004), who also observed the maximum number of tiller per square meter in 20 cm × 15 cm than other plant spacing.

Table 0: Effect of different planting geometry on number of tiller m^{-2} at different growth stages of DTR varieties at Narayani VDC, Nawalparasi, Nepal, 2014.

Treatments	Number of tiller m^{-2}			
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**
Varieties (A):				
Radha-4	304^{b}	348^{b}	338^{b}	317^{b}
Sukhadhan-5	330^{a}	384^{a}	368^{a}	352^{a}
Sukhadhan-4	303^{b}	345^{b}	334^{b}	320^{b}
LSD	**8.18**	**4.3**	**5.48**	**4.62**
SEm±	**2.79**	**1.46**	**1.86**	**1.57**
Spacing (B):				
15 cm × 10 cm	284^{d}	327^{d}	311^{d}	$290.^{d}$
15 cm × 15 cm	299^{c}	349^{c}	336^{c}	327^{c}
20 cm × 15 cm	349^{a}	397^{a}	383^{a}	364^{a}
20 cm × 20 cm	317^{b}	364^{b}	355^{b}	337^{b}
LSD	**9.45**	**4.9**	**6.33**	**5.33**
SEm±	**3.22**	**1.69**	**2.15**	**1.81**
CV%	**3.09**	**1.41**	**1.87**	**1.65**
Grand mean	**312**	**359**	**346**	**330**

Furthermore the numbers of tiller m^{-2} among rice varieties were also significantly difference. The difference in tiller production among varieties may be due to varietal character (Chandrashekhar *et al.*, 2001). Significantly highest number of tiller per square meter was recorded in Sukhadhan-5 (330), followed by Radha-4 (304) and lowest number of tiller per square meter was recorded by Sukhadhan-4 (303) at 30 DAT. Maximum number of tiller per square meter was observed at 45 DAT then after tiller number decreased due to tiller mortality. At 45 DAT Sukhadhan-5 produced the maximum number of tiller per square meter (384) followed by Radha-4 (348) and Sukhadhan-4 (345). Same trend of result was observed at 60 DAT and 75 DAT.

Effect on Leaf area index (LAI)

The LAI significantly ($p<0.01$) influenced by the both plant spacing as well as varieties (Table 5). The LAI value was increasing up to 60 DAT and thereafter decreased due to drying and senescence of leaves. Maximum LAI is found in 60 DAT in 15 cm × 10 cm plant spacing (9.2) and minimum in 20 cm × 20 cm plant spacing (2.1) at 30 DAT. Similar trend of LAI was observed in 45 DAT. At 60 DAT plant spacing 15 cm × 10 cm (9.2), 15 cm × 15 cm (9.1) recorded statistically similar LAI followed by 20 cm × 15 cm plant spacing (7.6). Similar trend of LAI observed in 75 DAT as well but lower than the 60 DAT it was due to senescence of leaves at maturity stage. The increased in LAI was contributed by the increased in tiller as well as number of leaves on each tiller and in size of the leaves. This result is in the line with Dingkuhn *et al.*, (1999); Campbell (2000) and Grigg *et al.*, (2000) who have reported that the maximum LAI values of rice ranging from 5.0-9.0 in various agro-ecological conditions and lowest in early stage of crop growth period. This result is also similar with Balasubramaniyan and Palaniappan (1991) and Cai *et al.* (1991), who have found the higher leaf area index in closer spacing than the wider spacing.

Regarding to varieties, the tested varieties were also significantly influenced the LAI. In all observation, Sukhadhan-5 recorded the highest LAI. Similar with the effect of plant spacing, highest LAI was found in 60 DAT and minimum in 30 DAT (Table 5). At 30 DAT Sukhadhan-5 recorded the maximum LAI (3.2) followed by Sukhadhan-4 (2.6) and Radha-4 (2.4). The LAI of Radha-4 and Sukhadhann-4 were statistically at par. Similar trend was also observed in other DAT. Sukhadhan-5 shown the maximum LAI at 60 DAT (9.4) followed by the Sukhadhan-4 (7.2) which was statistically at par with the Radha-4 varieties. At 75 DAT Sukhadhan-5 recorded the maximum LAI (6.0) which was at par with Radha-4 (4.7) and was statistically not differ with Sukhadhan-4 (4.7).

Effect on Dry Matter Production (g m^{-2})

In the experiment planting geometry and varieties both significantly influences the dry matter production statistically (Table 6). At, 30 DAT, significantly, higher dry matter production was found in 20 cm × 20 cm (121.9 g m^{-2}) spacing which is statistically at par with the spacing of 20 cm × 15 cm (117.3 g m^{-2}) where the lowest DM production was recorded in spacing 15 cm × 10 cm (69.4 g m^{-2}). The maximum amount of dry matter production was recorded in 75 DAT in spacing 20 cm × 20 cm (675.0 g m^{-2}), which was statistically at par with the spacing 20 cm × 15 cm (656.3 g

m^{-2}) and lowest amount of DM production was recorded in 30 DAT under spacing 15 cm × 10 cm (69.40 g m^{-2}). The higher dry matter production in wider spacing might be due to high amount of photosynthate accumulation during its growth stages. This may be due to more availability of PAR, nutrient and soil moisture as compared to closely spaced plants. This results also in agreed with the results of Villanaueva *et al.*, (1989); Singh *et al.*, (1989)' Miraz *et al.*, (2009), who were also reported the maximum DM production in wider spaced plant as compared to the closer plant spacing. Regarding varieties Sukhadhan – 5 produce the highest dry matter in all growth stages whereas Radha – 4 and Sukhadhan – 4 produces statistically similar dry matter.

Table 5: Effect of different planting geometry on LAI at different growth stages of DTR varieties in Narayani VDC, Nawalparasi, Nepal during 2014.

	Leaf area index (LAI)			
Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Varieties (A):				
Radha-4	2.4^b	5.6^b	7.2^b	4.7^b
Sukhadhan-5	3.2^a	7.0^a	9.4^a	6.0^a
Sukhadhan-4	2.6^b	5.6^b	7.5^b	4.7^b
LSD	**0.22**	**0.37**	**0.49**	**0.27**
SEm±	**0.07**	**0.12**	**0.16**	**0.09**
Spacing (B):				
15 cm × 10 cm	3.5^a	7.9^a	9.2^a	5.9^a
15 cm × 15 cm	2.9^b	6.6^b	9.1^a	5.9^a
20 cm × 15 cm	2.5^c	5.6^c	7.6^b	4.9^b
20 cm × 20 cm	2.1^d	4.3^d	5.9^c	3.9^c
LSD	**0.26**	**0.43**	**0.57**	**0.31**
SEm±	**0.08**	**0.14**	**0.19**	**0.10**
CV%	**9.62**	**7.19**	**7.29**	**6.15**
Grand mean	**2.72**	**6.12**	**7.94**	**5.13**

Table 6: Effect of different planting geometry on DM production at different growth stages of DTR varieties in Narayani VDC, Nawalparasi, Nepal during 2014.

	Dry matter production above ground level (g m^{-2})			
Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Varieties (A):				
Radha-4	94.7^b	218.0^b	465.0^b	524.7^b
Sukhadhan-5	111.9^a	255.0^a	465.0^a	642.2^a
Sukhadhan-4	94.8^b	215.0^b	364.9^c	501.6^b
LSD	**5.35**	**11.44**	**20.70**	**29.54**
SEm±	**1.82**	**3.90**	**7.05**	**10.07**
Spacing (B):				
15 cm × 10 cm	69.4^c	168.9^c	269.5^c	343.6^c
15 cm × 15 cm	93.3^b	220.0^b	396.0^b	549.7^b
20 cm × 15 cm	117.3^a	262.2^a	477.9^a	656. 3^a
20 cm × 20 cm	121.9^a	266.5^a	477.8^a	675.0^a
LSD	**6.17**	**13.21**	**23.89**	**34.12**
SEm±	**2.10**	**4.50**	**8.14**	**11.63**
CV%	**6.28**	**5.89**	**6.03**	**6.27**
Grand mean	**100.47**	**229.41**	**405.30**	**556.14**

Effect on Crop Growth Rate (CGR)

Statistically crop growth rate (CGR) significantly ($p<0.01$) influenced by the plant spacing and varieties (Table 7). At 30-45 DAT, the 20 cm × 15 cm plant spacing showed the highest CGR (9.7 g m^{-2} day^{-1}) and is statistically at par with the plant spacing 20 cm × 20 cm (9.7 g m^{-2} day^{-1}) and lowest CGR recorded in the plant spacing 15 cm × 10 cm (6.6 g m^{-2} day^{-1}). Statistically significant effect was found in CGR in 45-60 DAT where the maximum CGR was recorded in plant spacing 20 cm × 15 cm (14.4 g m^{-2} day^{-1}) which is statistically at par with the 20 cm × 20 cm plant spacing (14.1 g m^{-2} day^{-1}). Similarly, at 60-75 DAT, the plant spacing 20 cm × 20 cm showed the highest CGR (13.1 g m^{-2} day^{-1}) which was statistically at par with the plant spacing 20 cm × 15 cm (11.9 g m^{-2} day^{-1}). The maximum CGR at the wider spacing was due to the proper utilization of nutrient and moisture and interception of maximum solar radiation, which leads the faster growth of crop plant.

Table 7: Effect of different planting geometry on CGR at different growth stages of DTR varieties in Narayani VDC, Nawalparasi, Nepal during 2014.

	Crop Growth Rate (CGR) (g m^{-2} day^{-1})		
Treatments	30-45 DAT	45-60 DAT	60-75 DAT
Varieties (A):			
Radha-4	8.2^b	11.2^b	9.2^b
Sukhadhan-5	9.5^a	14.0^a	11.8^a
Sukhadhan-4	8.0^b	10.0^c	9.1^b
LSD	**0.62**	**0.82**	**1.50**
SEm±	**0.21**	**0.28**	**0.51**
Spacing (B):			
15 cm × 10 cm	6.6^c	6.7^c	4.9^c
15 cm × 15 cm	8.4^b	11.7^b	10.2^b
20 cm × 15 cm	9.7^a	14.4^a	11.9^{ab}
20 cm × 20 cm	9.7^a	14.1^a	13.1^a
LSD	**0.72**	**0.96**	**1.74**
SEm±	**0.24**	**0.32**	**0.59**
CV%	**8.51**	**8.35**	**17.7**
Grand mean	**8.59**	**11.72**	**10.05**

Regarding the effect on varieties, Sukhadhan-5 produced the maximum CGR compared to other tested varieties in all stage. At 30-45 DAT Sukhadhan-5 produced the maximum CGR (9.5 g m^{-2} day^{-1}) followed by the Radha-4 (8.2 g m^{-2} day^{-1}) which was statistically at par with the Sukhadhan-4. Similar trend was observed in 60-75 DAT. But at 45-60 DAT, Sukhadhan-4 produced the lowest CGR (10.0 g m^{-2} day^{-1}) while Sukhadhan-5 produced the highest CGR (14.0 g m^{-2} day^{-1}). The variety Sukhadhan-5 produced the highest CGR which might be due to maximum LAI which ultimately enhance the photosynthetic rate and accumulation of photosynthate very efficiently.

Conclusion

Thus, the planting geometry 15 cm × 10 cm produced the highest plant height and LAI. Similarly, planting geometry

20 cm × 15 cm recorded the maximum number of tiller m^{-2} and CGR at initial stage while in later stage planting geometry 20 cm × 20 cm recorded the maximum CGR and DM. Regarding the varieties sukhadhan-5 recorded the highest number of tiller m^{-2}, LAI, DM and CGR whereas sukhadhan-4 recorded the highest plant height.

Reference

Anwar MP, Juraimi AS, Puteh A, Selamat A, Man A and Hakim MA (2011) Seeding method and rate influence on weed suppression in aerobic rice. *African J Biotechnol* **10**(68): 15259-15271. DOI: 10.5897/AJB11.060

Balasubramaniyan P and Palaniappan SP (1991) Effect of population density, fertilizer levels and time of application on rice. *Indian J. Agron,* **36**(2): 218-221.

Bezbaruha R, Sharma RC and Banik P (2011) Effect of Nutrient Management and Planting Geometry on Productivity of Hybrid Rice (*Oryza sativa* L.) Cultivars. *American Journal of Plant Sciences* **2**: 297-302. DOI: 10.4236/ajps.2011.23033

Brown RH (1984) Growth of the green plant. Physiological Basis of Crop Growth and Development. ASA. CSSA. Madison, Wisconsin, USA, pp: 153-173.

Cai YZ, Cheng GF, Wu HM and Xue YS (1991) Investigation of target for yield components and the establishment of relative population for the high yielding *Japonica* rice hybrid 'Han You 102'. *Acta Agric* **7**(3): 41-45.

Campbell CS (2000) A field scale study of earhon, water and energy flow in irrigated rice. Thesis, Ph.D. Texas A&M University, Texas. 172 p.

Dingkhun M, Johnson DE, Samb A, Diack S and Asch F (1999) Relationship between upland rice canopy characteristics and weed competitiveness. *Field Crops Research* **61**: 79-95. DOI: 10.1016/S0378-4290(98)00152-X

FAOSTAT (2013) Food and Agriculture Organization Statistics Division.

Garcia FD, Escabarte RSJR, Sta Cruz PC and Obein SR (1992) Improving the yield potential of lowland rice varieties through appropriate plant spacing and nitrogen management. *Philippine J Crop Sci* **17**(1): 26.

Gautam JC (2008) Country report on the state of plant genetic resources for food and agriculture. Retrieved from: http://www.fao.org/docrep/013/i1500e/Nepal.pdf.

Gomez KA and Gomez AA (1984) Statistical Procedure of Agricultural Research. 2nd edition. John Wiley and Sons Inc. New York.

Grigg BC, Beyrouty CA, Norman RJ, Gbur EE, Hanson MG and Wells BR (2000) Rice response to changes in flood water and N timing in southern USA. *Field Crops Research* **66**: 73-79. DOI: 10.1016/S0378-4290(00)00065-4

IPCC (2007) Climate change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland. pp 104

Jones JM and Sheats DB (2016) Consumer Trends in Grain Consumption. St. Catherine University., St Paul, MN, USA. Elsevier Ltd.

Kamoshita A, Rodriguez R, Yamauchi A and Wade L (2004) Genotypic variation in response of rainfed lowland to prolonged drought and re-watering. *Plant Production Science* **7**(4): 406–420. DOI: 10.1626/pps.7.406

Lama S and Devkota B (2009) Vulnerability of mountain communities to climate change and adaptation strategies. *The Journal of Agriculture and Environment* **10**: 73-83. DOI: 10.3126/aej.v10i0.2133

Luo LJ and Zhang QF (2001) The status and strategy on drought resistance of rice (*Oryza sativa* L.). *Chinese J Rice Sci* **15**: 209–214.

Miah MHN, Karim MA, Rahman MS and Islam MS (1990) Performance of Nizersail mutants under different row spacing. Bangladesh J. Train. Dev. 3(2): 31-34.

MOAD (2014) Statistical information on Nepalese agriculture. Government of Nepal Ministry of Agricultural Development Agri Business Promotion and Statistics Division. Agri-statistics Section Singha Durbar, Kathmandu Nepal.

Mohammad A, Khan MA, Khan EJ and Muhammad R (2004) Effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. Faculty of Agriculture, Gomal University, Dera Ismail Khan.

NARC (2007) Research Highlights: 2002/03-2006/07. Communication, Publication and Documentation Division, Nepal Agricultural Research Council, Khumaltar. Lalitpur, Nepal.

Om H, Singh OP and Joon RK (1993) Effect of time of transplanting and spacing on Basmati rice. *Haryana J Agron* **9**(1): 87.

Palaniswamy KM and Gomez KA (1974) Length-width method for estimating leaf area of rice. Agronomy journal. *An American society of Agronomy publication* **66**(3): 430.

Rasool F, Habib R and Bhat MI (2013) Agronomic evaluation of rice (*Oryza sativa* L.) for plant spacing and seedlings per hill under temperate condition. *African Journal of Agricultural Research* **8**(37): 4650-4653. DOI: 10.5897/AJAR10.411

Rodriguez RC and Ingram KT (1991) Establishment and yield of rainfed lowland dry seeded rice as influenced by row spacing. *Philippine J Crop Sci* **16**(1): S10.

Sapkota S, Paudel MN, Thakur NS, Nepali MB and Neupane R (2010) Effect of climate change on rice production: A case of six VDCs in Jumla district. *Nepal Journal of Science and Technology* 11: 57-62.

Shah MH, Khushu MK, Khandey BA and Bali AS (1991) Effect of spacing and seedling per hill on transplanted rice under late sown conditions. *Indian J Agron* **36**(2): 274-275.

Singh S, Prasad R and Sharma SN (1989) Growth and yield of rice as affected by spacing, time and depth of placement of urea briquettes. *Fert Res* **19**(2): 99-101. DOI: 10.1007/BF01054681

Villanueva JD, Jamilarin JD, Daguro LL, Pablico PP, Moody K, Cabayao EL and Osana JM (1989) Effect of plant spacing and Salvinia molesta on yield of transplanted rice (*Oryza sativa*). Conference on Pest Control Council of the Philippines, Baguio City (Philippines), May 1989. International Rice Research Inst., Los Banos, Laguna (Philippines). pp: 9-12

.