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Assessment of physiological parameters of *Rabi* blackgram (*Vigna mungo* L.) varieties under different sowing windows

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Abstract
A field experiment was conducted at the College Farm, Agricultural College, Mahanandi of Acharya N.G. Ranga Agricultural University during the period from October, 2017 to January 2018 to evaluate the Crop Growth Rate, Relative Growth Rate and Net Assimilation Rate of *Rabi* blackgram (*Vigna mungo* L.) under different sowing windows. The experimental site was sandy loam and it was neutral in reaction with a P^H of 7.30, Ec of 0.20 ds m^{-1}. The experiment comprised four blackgram varieties *viz.*, TBG-104, LBG-787, GBG-1 and PU-31 and four sowing dates *viz.*, 1st fort night of October, 2nd fort night of October, 1st fort night November and 2nd fort night November. The experiment was laid out in randomized block design with factorial concept (FRBD) having sixteen treatments and three replications. Results showed that varieties and dates of sowings significantly influenced the parameters. The growth attributing experimentation characters such as plant crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) was found highest in PU-31 and lowest in LBG-787. With regard to sowing windows, the higher as well as lower values of these parameters were observed with sowing 1st fort night of October and 2nd fort night of November, respectively.

Keywords: Blackgram, *Vigna mungo*, physiological parameters and sowing windows

Introduction
Pulses are one among the primary dietary protein source of which Black gram (*Vigna mungo* (L.) Hepper), commonly referred to as urdbean in India, is a significant short-duration pulse crop that is self-pollinating and diploid (2n=22), with a small genome size estimated to be 0.56pg/1C (574 Mbp) (Gupta *et al*., 2008) [1].According to Iriti and Varoni (2017) [2], pulses have always been the most significant food grain used to make staple foods that meet people's basic needs for protein and energy. Black gram originated on the Indian subcontinent, according to Vavillov (1926) [11] Center of genetic diversity for black gram is found in India (Zeven *et al*., 1982) [12]. India is major producer and consumer of blackgram (Raju, 2019) [7]. Blackgram (*Vigna mungo* L.) belongs to family Fabaceae sub family papilionaceae, is being grown as one of principle pulse crop. The states that produce the most amount of pulses are Madhya Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Karnataka, and Bihar.In India, it is cultivated in an area of 2.346 M ha with a production of 1.959 M t. In Andhra Pradesh, it occupies an area of 0.315 M ha with production of 0.298 M t. The average productivity of blackgram in Andhra Pradesh (946 kg ha^{-1}) is high as compared to India's productivity (604 kg ha^{-1}) (Indiastat, 2015).
By 2030, India's population is expected to have increased from 1.21 billion in 2015 to 1.68 billion. With an estimated growth rate of 4.2%, the estimated pulse requirement for 2030 would be 32 million tonnes, up from the current level of 15 million tonnes. Meanwhile, the country's per capita availability of pulses has declined from 69 g in 1961 to 37 g in 2016–17, raising serious concerns. To alleviate protein energy malnutrition, a minimum of 50g pulses/capita/day should be available in addition to other sources of protein.
In this context, there is an urgent need to increase the production levels of pulses to meet the increasing demand by manipulating the production techniques. To fulfill our future requirement, it is must to follow the scientific production of pulses

Amongst all the factors of crop production, timely sowing is important in all crops and in all seasons as time of sowing will influence the yield and growth of the crops to the most and the date of sowing determine time of flowering and dry matter accumulation, seed set and seed yield. During *kharif* season, the major constraints are high humidity associated with luxurious vegetative growth, high insect-pest, diseases and less fruit setting etc. In order to save the crop from adverse effects of excess moisture during *kharif* season, cultivation of blackgram during *rabi* season or early summer may be beneficial where ever irrigation facilities are available (Reddemma *et al*. 2024) [8]. Moreover, in recent years interest has been on the farmers for replacing many of traditional crops in late *Kharif* and *Rabi* with blackgram as the returns are more due to relatively more remunerative prices of blackgram compared to traditional cereal crops and also the duration of blackgram is smaller in nature. Among the agronomic practices limiting the yield even under irrigated conditions is the choice of suitable dates of sowing and variety. Hence, the present experiment is proposed to find out the response of physiological parameters of *Rabi* blackgram (*Vigna mungo* L.) to different dates of sowing.

Materials and Methods

A field trail was carried out at College Farm, Agricultural College, Mahanandi campus of Acharya N. G. Ranga Agricultural University during *rabi*, 2017-18. The experiment laid out in a factorial randomized block design consisting of sixteen treatments consisting of four varieties of blackgram (V_1: TBG-104, V_2: LBG-787, V_3: GBG-1 and V_4: PU-31) and four dates of sowing (D_1:1^{St}FN of October, D_2:2^{nd} FN of October, D_3:1^{St} FN of November, D_4:2^{nd} FN of November) and replicated thrice. The spacing adopted for sowing is 30 X 10 cm. the varietal characteristic features were mentioned below in detail:

V_1: TBG-104: The variety TBG-104 is a photo insensitive variety suitable for cultivation in all the seasons under upland conditions. It is early maturing variety (75 days) with dark green foliage.

V_2: LBG-787 It is also photo insensitive suitable for cultivation in all the seasons including rice fallow situation. Duration of crop maturity is 75-80 days.

V_3: GBG-1: Bold seed variety is suitable for all seasons, tolerant to yellow mosaic with crop duration is 80-90 days.

V_4: PU-31: This variety matures in 85-90 days (medium) and is widely adaptive, popular and high yielding variety and resistant YMV disease. It is suitable for all seasons.

The data on physiological parameters like CGR, RGR and NAR were collected at 30 DAS, 60 DAS and at harvest from the all *Rabi* blackgram varieties tested in experimentation. The computation of physiological parameters were done by the following formulae. The collected data on physiological parameters was analysed statistically by using the critical difference 0.05 percent level of significance to compare different treatments.

Crop growth rate (CGR): Crop growth rate was worked out between 30,60DAS and at harvesting after sowing by using the formula (Watson, 1952) expressed as g m^{-2} day^{-1}.

$$CGR=\frac{W_2-W_1}{T_2-T_1} X \frac{1}{P}$$

Whereas W_2 and W_1 represents plant dry weights at times T_2 and T_1 respectively and P is the land area.

Relative growth rate (RGR): Relative growth rate was worked out between 30, 60 and at harvesting–day–after sowing by using the formula (Watson, 1952) and expressed as g.

$$RGR=\frac{\text{Loge } w_2\text{- loge } w_1}{T_2-T_1} X\ 100$$

Whereas, W_2 and W_1 are the total dry weights at times T_2 and T_1 respectively

Net Assimilation Rate (NAR): Net assimilation rate is a measure of increase of dry weight per unit leaf area. NAR was worked out between 30,60DAS and at harvestingafter sowing by using the formula (Gregory, 1926) and expressed as g m^{-2} day^{-1}.

$$NAR=\frac{W2-W1}{T2-T1} X \frac{\log_e A_2-\log_e A_1}{A_2-A_1}$$

Whereas, W_2 and W_1 are the final and initial dry weights, respectively. A_2 and A_1 are the leaf areas at times and T_2 and T_1 are the interval time.

Results and Discussion

The effect of sowing windows on Crop Growth Rate of rabi blackgram varieties

Crop growth rate in blackgram was significantly influenced by varieties and dates of sowing at 30, 60 DAS and at harvest. The crop growth was increased by total dry matter and leaf area. The interaction between varieties and dates of sowing in crop growth rate was found to be non-significant at all stages of (30 DAS to 60 DAS and 60 DAS to harvest) of crop growth during the study.

Crop Growth Rate at 30-60 DAS: The significant variation in crop growth rate of blackgram was recorded for different varieties and dates of sowing at 30-60 DAS (Table: 1)
The highest crop growth area (6.62 g m^{-2} day^{-1}) was found in V_4 (PU-31) which was followed (6.34 g m^{-2} day^{-1}) by V_3 (GBG-1) and the low crop growth rate (5.94 g m^2 day^{-1}) was recorded in V_2 (LBG-787) which was on par (6.04 g m^{-2} day^{-1}) with V_1 (TBG-104) at 30-60 DAS.
Crop growth rate of blackgram at 30-60 DAS varied significantly due to different sowing dates, the highest crop growth rate (7.10 g m^{-2} day^{-1}) was recorded in D_1 (Sowing on 1^{st} fort night of October), which was closely followed by D_2(6.82 g m^{-2} day^{-1}-Sowing on 2^{nd} fort night of October) and the low crop growth rate (5.02 g m^{-2} day^{-1}) was obtained in D_4 (Sowing on 2^{nd}fort night of November), which was on par (5.97g m^{-2} day^{-1}) with D_3 (Sowing on 1^{st} fort night of November).

Crop Growth Rate at 60DAS-harvest: The significant variation wasobserved in crop growth rate of blackgram for different varieties at 60 DAS-harvest (Table: 2).
The highest crop growth rate (23.38 g m^{-2} day^{-1}) was found in V_4 (PU-31), which was statistically on par (23.29 g m^{-2} day^{-1}) with V_3 (GBG-1) while the low crop growth rate (21.61 g m^{-2} day^{-1}) was recorded in V_2 (LBG-787) which was on par (21.72 g m^{-2} day^{-1}) with V_1 (TBG-104) at 60DAS-harvest.
Crop growth rate of blackgram at 60DAS-harvest varied significantly due to different sowing dates. The highest crop

growth rate (24.95 g $m^{-2}day^{1}$) was recorded in D_1 (Sowing on 1st fort night of October), which was closely followed by D_2 (23.31 g m^{-2} day^{-1}-Sowing on 2ndfort night of October) and the low crop growth rate was recorded (18.69 g m^{-2} day^{-1}) in D_4 (Sowing on 2nd fort night of November), which was on par (23.03 g m^{-2} day^{-1}) with D_3 (Sowing on1st fort night of November).

The maximum CGR was observed with V_4 (PU-31) and D_1 (Sowing on 1st fort night of October) during pod filling stage due to maximum leaf area index and dry matter accumulation than other varieties and dates of sowing of blackgram crop. These results were in conformity with the findings of Kumar *et al.* (2009) [3], Mondal *et al*. (2012) [5] and Sritharan *et al.* (2015) [9].

The effect of sowing windows on Relative Growth Rate of rabi blackgram varieties

Relative growth rate in blackgram was significantly influenced by varieties and dates of sowing at 30-60 DAS, 60DAS and at harvest. The relative growth rate increased progressively from 30 to 60 DAS but declined as the crop reached harvest stage. The treatment V_2D_4 recorded lowest relative growth rate at all the stages of crop growth.The interaction between varieties and dates of sowing in recording relative growth rate was found to be non-significant at all growth stages of (30 DAS to 60 DAS and 60 DAS to harvest) of crop during the study.

Relative Growth Rate at 30-60DAS: The significant variation wasrecorded in relative growth rate of blackgram different varieties at 30-60DAS (Table: 3).

The highest relative growth rate was found in V_4 (PU-31) (0.56 mg g^{-2} day^{-1}) at 30-60DAS, which was statistically on par with V_3 (GBG-1) (0.53 mg $g^{-2}day^{-1}$) while the lowest relative growth rate was found in V_2 (LBG-787) (0.49 mg g^{-2} day^{-1}), which was followed by (0.52 mg g^{-2} day^{-1}) by V_1 (TBG-104).

With regard to different sowing dates, the highest relative growth rate was recorded in D_1 (0.59 mg g $^{-2}$ day^{-1}) (Sowing on 1st fort night of October), which was followed (0.56 mg g^{-2} day^{-1}) by D_2 (Sowing on 2nd fort night of October) and while the lowest relative growth rate (0.43 mg g^{-2} day^{-1}) was recorded in D_4 (Sowing on 2nd fort night of November), which was on par (0.53 mg g^{-2} day^{-1}) with D_3 (Sowing on 1st fort night of November).

Relative Growth Rate at 60 DAS-harvest: The significant variation inrelative growth rate of blackgram was recorded for different varieties and dates of sowing at 60DAS-harvest (Table: 4).

With regard to varieties, the highest relative growth rate was found in V_4 (PU-31) (0.36 mg g^{-1} day^{-1}) which were statistically similar with V_3 (GBG-1) (0.35 mg g^{-1} day^{-1}) and the lower relative growth rate (0.33 mg g^{-1} day^{-1}) was recorded similar in V_1 (TBG-104) and followed by V_2 (LBG-787). Relative growth rate of blackgram at 60DAS-harvest varied significantly due to different sowing dates. The highest relative growth rate (0.37 mg g^{-1} day^{-1}) was recorded in D_1 (Sowing on 1st fort night of October), which was statistically similar (0.36 mg g^{-1} day^{-1}) with D_2 (Sowing on 2nd fort night of October) while the lowest relative growth rate (0.31 mg g^{-1} day^{-1}) was obtained from D_4 (Sowing on 2nd fort night of November), which was on par (0.32 mg g^{-1} day^{-1}) with D_3 (Sowing on 1st fort night of November).

The higher relative growth rate might be due to better reproductive growth phase, more production of functional leaves and higher CGR ofblackgram crop Similar results were also reported by Kumar *et al.* (2009) [3], Mondal *et al.* (2012) [5], Marthupandi *et al.*(2016) and Rajput and Rajput. (2017) [6].

The effect of sowing windows on Net Assimilation Rate of rabi blackgram varieties

Net assimilation rate in blackgram was significantly influenced by varieties and dates of sowing at 30, 60 DAS and at harvest.

Net Assimilation Rate at 30-60DAS: The significant variation was recorded for net assimilation rate of blackgram with different varieties and sowing windows at 30-60DAS (Table 5).

Among different varieties, the highest net assimilation rate (0.34 mg cm^{-2} day^{-1}) was found in V_4 (PU-31), which was statistically similar (0.33 mg cm^{-2} day^{-1}) with V*3* (GBG-1) and the lowest net assimilation rate (0.31 mg cm^{-2} day^{-1}) was recorded statistically similar in V_1 (TBG-104) and V_2 (LBG-787).Data on net assimilation rate of blackgram at 30-60DAS varied significantly due to different sowing windows. The highest net assimilation rate (0.38 mg $cm^{-2}day^{-1}$) was recorded in D_1 (sowing on 1st fort night of October), which was followed (0.35 mg $cm^{-2}day^{-1}$) by D_2 (sowing on 2nd fort night of October) and the lowest net assimilation rate (0.27 mg cm^{-2} day^{-1}) was obtained from D_4 (sowing on 2nd fort night of November), which was on par (0.30 mg $cm^{-2}day^{-1}$) with D_3 (sowing on1st fort night of November).

Net Assimilation Rate at 60DAS-harvest: The significant variation was recorded for net assimilation rate of blackgram for different varieties and dates of sowing windows at 60DAS to harvest (Table 6).

Data regarding varieties, the highest net assimilation rate (0.40 mg cm^{-2} day^{1}) was found in V_4 (PU-31) which were statistically similar (0.39 mg cm^{-2} day^{1}) with V_3 (GBG-1) while the lowest net assimilation rate (0.38 mg $cm^{-2}day^{-1}$) was recorded in V_2 (LBG-787) which was on par (0.37mg cm^{-2} day^{-1}) with V_1 (TBG-104).

Net assimilation rate of blackgram at 60 DAS and harvest varied significantly due to different sowing dates. The highest net assimilation rate (0.45 mg $cm^{-2}day^{-1}$) was recorded in D_1 (Sowing on 1st fort night of October), which was followed (0.39 mg $cm^{-2}day^{-1}$) by D_2 (Sowing on 2nd fort night of October) and the low net assimilation rate (0.34 mg cm^{-2} day^{-1}) was obtained from D_4 (Sowing on 2nd fort night of November), which was on par (0.36 mg $cm^{-2}day^{-1}$) with D_3 (Sowing on1st fort night of November).

The higher net assimilation rate might be due to better reproductive growth phase, more production of functional leaves and higher LAI, CGR, RGR of blackgram crop Similar results were also reported by Mondal *et al*. (2012) [5], Surendra *et al*. (2013) [10], Sritharan *et al*. (2015) [9] and Maruthupandi (2016) [4].

Statistically significant differences were recorded due to the interaction effect of variety and sowing date for net assimilation rate at 60 DAS and harvest. The highest net assimilation rate (0.47 mg $cm^{-2}day^{-1}$) was recorded from V_4D_1 (PU-31) and Sowing on 1st fort night of October) and the lowest net assimilation rate (0.33 mg $cm^{-2}day^{-1}$) was recorded from V_2D_4 (LBG –787) and Sowing on 2nd fort night of November).

Table 1: Crop growth rate (g m^{-2} day^{-1}) of blackgram as influenced by varieties and dates of sowing at 30-60 DAS

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	6.99	6.86	7.20	7.36	7.10
D_2: (October 2nd FN)	6.75	6.78	6.93	6.84	6.82
D_3: (November 1st FN)	6.06	5.27	5.97	6.59	5.97
D_4: (November 2nd FN)	4.37	4.84	5.26	5.71	5.02
Mean	6.04	5.94	6.34	6.62	

	SEm±	**CD (P=0.05)**
Varieties (V)	0.18	0.52
Dates of sowing (D)	0.18	0.52
Interaction (VXD)	0.36	**NS**

Table 2: Crop growth rate (g m^{-2} day^{-1})of blackgram as influenced by varieties and dates of sowing at 60 DAS – harvest

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	23.98	25.21	25.36	25.26	24.95
D_2: (October 2nd FN)	21.97	22.39	24.14	24.77	23.31
D_3: (November 1st FN)	22.40	21.12	24.69	24.92	23.03
D_4: (November 2nd FN)	18.52	17.70	19.00	19.55	18.69
Mean	21.72	21.61	23.29	23.38	

	SEm±	**CD (P=0.05)**
Varieties (V)	0.39	1.21
Dates of sowing (D)	0.39	1.21
Interaction (VXD)	0.78	NS

Table 3: Relative growth rate(mg g-2 day-1) of blackgram at 30-60 DAS as influenced by varieties and dates of sowing

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	0.57	0.57	0.58	0.62	0.59
D_2: (October 2nd FN)	0.58	0.52	0.57	0.59	0.56
D_3: (November 1st FN)	0.54	0.48	0.53	0.55	0.53
D_4: (November 2nd FN)	0.60	0.38	0.45	0.49	0.43
Mean	0.52	0.49	0.53	0.56	

	SEm±	**CD (P=0.05)**
Varieties (V)	0.01	0.02
Dates of sowing (D)	0.01	0.02
Interaction (VXD)	0.02	NS

Table 4: Relative growth rate (mg g^{-2} day^{-1}) of blackgram at 60 DAS-harvest as influenced by varieties and dates of sowing

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	0.37	0.35	0.37	0.40	0.37
D_2: (October 2nd FN)	0.33	0.36	0.36	0.39	0.36
D_3: (November 1st FN)	0.32	0.31	0.33	0.33	0.32
D_4: (November 2nd FN)	0.28	0.30	0.32	0.32	0.31
Mean	0.33	0.33	0.35	0.36	

	SEm±	**CD (P=0.05)**
Varieties (V)	0.01	0.01
Dates of sowing (D)	0.01	0.01
Interaction (VXD)	0.01	NS

Table 5: Net assimilation rate (mg cm-2 day-1) of blackgram as influenced by varieties and dates of sowing at 30-60 DAS

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	0.38	0.36	0.38	0.39	0.38
D_2: (October 2nd FN)	0.33	0.34	0.35	0.36	0.35
D_3: (November 1st FN)	0.27	0.27	0.32	0.33	0.30
D_4: (November 2nd FN)	0.26	0.26	0.27	0.28	0.27
Mean	0.31	0.31	0.33	0.34	

	SEm±	CD (P=0.05)
Varieties (V)	0.01	0.01
Dates of sowing (D)	0.01	0.01
Interaction (VXD)	0.01	NS

Table 6: Net assimilation rate (mg cm^{-2} day^{-1}) of blackgram at as influenced by varieties and dates of sowing 60 DAS- harvest

	Varieties				
Dates of sowing	**V_1 (TBG-104)**	**V_2 (LBG-787)**	**V_3 (GBG-1)**	**V_4 (PU-31)**	**Mean**
D_1: (October 1st FN)	0.43	0.45	0.45	0.47	0.45
D_2: (October 2nd FN)	0.37	0.38	0.41	0.42	0.39
D_3: (November 1st FN)	0.34	0.35	0.37	0.39	0.36
D_4: (November 2nd FN)	0.33	0.33	0.34	0.34	0.34
Mean	0.37	0.38	0.39	0.40	

	SEm±	CD (P=0.05)
Varieties (V)	0.01	0.01
Dates of sowing (D)	0.01	0.01
Interaction (VXD)	0.01	NS

Summary and Conclusion

The highest crop growth rate (7.10 and 24.95 g m^{-2}day^{-1}) was observed in D_1 and the lowest CGR (5.02 and 18.69 g m^{-2}day^{-1}) was found in D_4. The highest relative growth rate (0.59 and 0.37 mg g^{-1}day^{-1}) was observed in D_1 and the lowest RGR (0.43 and 0.31 mg g^{-1}day^{-1}) was found in D_4. The highest net assimilation rate (0.38 and 0.45 mg cm^{-2}day^{-1}) was observed in D_1 and the lowest NAR (0.27 and 0.34 mg cm^{-2}day^{-1}) was found in D_4.

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