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Physiological assessment of growth and yield of six maize hybrids in relation to growing degree days

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Abstract

An experiment was under taken at the Agricultural College farm, Bapatla during two consecutive years of *rabi* 2016-17 and 2017-18. The crop growth stages of maize are dependent on various morphological, anatomical and physiological parameters. The experiment was laid out in randomized block design with six maize hybrids *viz.*, 900M Gold, DKC 9142, DKC 9120, DKC 9081, DKC 9042 and Pinnacle in four replications. CGR and NAR was found to be the highest at 57 to 63 DAS among all the hybrids during both the seasons where CGR was found to be the highest DKC 9142 followed by Pinnacle which were at par with each other. Whereas, pinnacle recorded highest NAR followed by DKC 9142. Among all the hybrids, RGR was found to be maximum at 50 to 56 DAS coinciding with reproductive primordial development. The yield and yield attributing characters such as length of the cob, number of rows per cob, number of kernels per row, 100 seed weight and the total kernel yield showed significant variation among the hybrids where the highest yield was obtained in pinnacle (9641.41 kg ha⁻¹) and DKC 9142 (9243.9 kg ha⁻¹).

Keywords: CGR, RGR, NAR, LAI, cob/ear, RBD and kernel yield

1. Introduction

Maize is the world's third most important cereal crop after wheat and rice. The maize production in India during 2015-16 stood at 22 million tonnes with an area of 9.2 million hectares. The total production is 4.23 million tonnes with an area of 1.0 million hectares in Andhra Pradesh (AICRP, 2016) [1]. The maize productivity in India during 2014-15 was 2.56 t/ha (AICRP, 2016) [1]. Due to its more genetic diversity, it can be grown over a wide range of environmental conditions. Growth analysis parameters like crop growth rate (CGR) are product of LAI. The higher LAI in closer plant geometry might be due to more number of leaves produced per unit area. The significantly increasing of NAR with increase in plant geometry at maximum leaf number and complete reproductive stage (all the growth stages). Relative growth rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at a given point of time and net assimilation rate (NAR) is the net gain in total dry matter per unit leaf area per unit time. The dry matter yield or increase in kernel yield is mainly attributed to kernel weight of the cob as well as partitioning of dry matter in to different components.

2. Material and Methods

The experiment was conducted in field number 8, Orchard block of Agricultural College farm, Bapatla. The farm is geographically located on the eastern side of peninsular India, situated at an altitude of 5.49 m above mean sea level, 15°54' Northern latitude, 80°25' Eastern longitude and about 7 km away from Bay of Bengal in Agro-climatic Zone III of Andhra Pradesh.

The data pertaining to various weather elements during crop growth period in *rabi* season of both the years 2016-17 and 2017-18 were recorded from the meteorological observatory of IMD located at the Agricultural College Farm, Bapatla are presented in Tables 1 and 2.

2.1 Leaf area index (LAI)

The leaf area index is the ratio of leaf area to that of ground area. It was estimated using the formula (Watson, 1952) [15].

$$LAI = \frac{A}{P} \text{ Where, } A = \text{Leaf area}$$

$$P = \text{Ground area}$$

2.2 Crop growth rate ($\text{g m}^{-2} \text{d}^{-1}$)

It is the rate of dry matter production per unit ground area per unit time. The crop growth rate was estimated by using the formula of Watson (1952)^[15] and expressed in $\text{g m}^{-2} \text{day}^{-1}$.

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P} \text{ g m}^{-2} \text{ day}^{-1}.$$

Where

W_1 = Total plant dry matter at time t_1

W_2 = Total plant dry matter at time t_2

P = ground area

t_1 and t_2 = time in days

2.3 Relative growth rate ($\text{g g}^{-1} \text{d}^{-1}$)

Blackman (1919)^[5] considered the rate of increase in dry matter of plants as a process of continuous compound interest, where in the increment in any interval adds to the capital for subsequent growth. The rate of increment is known as 'Relative Growth Rate' (RGR) and was calculated according to the following formula.

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \text{ g g}^{-1} \text{ d}^{-1}$$

Where

W_1 = Total plant dry weight at time t_1

W_2 = total plant dry weight at time t_2

t_1 and t_2 = time in days

The RGR was worked out at seven days interval from sowing to harvest and the average values were computed.

2.4 Net assimilation rate ($\text{mg cm}^{-2} \text{d}^{-1}$)

Net assimilation rate (NAR) is the increase in weight of dry matter of a plant per unit leaf area per unit time and was calculated according to the formula given by Williams (1946)^[16].

$$\text{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1} \text{ mg cm}^{-2} \text{ d}^{-1}$$

Where, W_1 and W_2 represents dry matter at the beginning and end of the time t_1 and t_2 respectively. A_1 and A_2 represents the leaf area at time t_1 and t_2 respectively. The NAR values were worked out at weekly intervals from sowing to harvest and the average values were computed.

2.5 Growing Degree Days (GDD)

During the growth period of maize the daily temperature variations were recorded since the crop inception in the field *i.e.*, seed germination to cob harvest. Growing degree days are an arithmetic accumulation of daily mean temperatures above certain threshold levels (Table 1 and 2).

$$\begin{aligned} \text{Growing Degree Days (GDD)} \\ &= \sum [Max \text{ temp} + Min \text{ temp} / 2] \\ &\quad - \text{Base temperature} \end{aligned}$$

2.6 Yield and yield attributes

Five tagged plants in each sub plot were used for recording morphological characters and were harvested at physiological maturity and used for recording the following yield and its components.

2.6.1 Length of the cob

The cobs were removed from the five tagged plants plot wise and their length was measured and expressed in centimetres.

2.6.2 Number of rows per cob

Of the each cob harvested from five tagged plants plot wise, the number of rows per cob were counted.

2.6.3 Number of kernels per row

In each cob, five rows were selected and the number of kernels per row was counted and the average was expressed as kernels per row.

2.6.4 100 seed weight (g)

A lot of seeds that were randomly drawn from the four replications of each treatment and a multiple number of 100 seeds were weighed and computed.

2.6.5 Total kernel yield (Kg ha^{-1})

Harvested cobs were dried for 15 days followed by shelling plot wise. The kernel weight was calculated for net plot area and it was computed to hectare and expressed as Kg ha^{-1}

2.7 Statistical analysis

The data were analyzed by following the analysis of variance (ANOVA) technique as suggested by Panse and Sukhatme (1978)^[10]. The statistical hypothesis of equalities of treatment means was tested by the test in ANOVA at 5 per cent level of significance to compare different treatment means.

3. Results and Discussions

Maize is an economically important crop because of its widespread commercial production and utilization. It is well known that nutrient deficiency in most cultivated crops during the growth season causes imbalance, leading to low productivity and reduction in yield.

3.1 Leaf area index (LAI)

Leaf area index is an important variable characterizing the development of crop and its exchanges with atmosphere. Along with various agronomical practices, proper distribution of crop plants per unit area and efficient utilization of available nutrients and other resources are needed. The environmental factors such as photosynthetically active radiation (PAR), light interception, radiation, chlorophyll index and other photosynthetic parameters influences the final grain yield (Andrieu, 1997)^[4].

The data on leaf area index measured at seven days interval from seedling to harvest were presented in Table 3 and Fig.1 At 7 DAS, Leaf area index (LAI) was significantly high in Pinnacle followed by DKC 9142 and low in 900M Gold compared to other three hybrids. At 14 DAS, DKC 9142 had greater LAI than DKC 9081, DKC 9042 and on par with Pinnacle, DKC 9120 and 900M Gold. At 21 DAS, Pinnacle had the LAI 1.27, superior to all other hybrids (1.01 to 1.10). At 28 DAS, LAI was significantly high in Pinnacle followed by DKC 9142, DKC 9042 and 900M Gold over DKC 9081 and DKC 9120. At 35 and 49 DAS, Pinnacle had high LAI superior to DKC 9042 and on par with other four hybrids. At 42 DAS, Pinnacle significantly dominated the hybrid DKC 9120, but on par with other four hybrids. Later the LAI of hybrids didn't vary. The six hybrids attained the maximum LAI at 70 DAS, where the growing degree days accumulated was 1028. Later on LAI decreased.

During *rabi* 2017-18, the differences among hybrids in LAI at 7 DAS were negligible, significantly low in DKC 9120 compared to others, which were on par with each other (Table 4 and Fig. 2). At 14 DAS, DKC 9142, DKC 9120 and Pinnacle possessed LAI 0.86 to 0.89, greater than other three.

From 21 to 42 DAS and at 56 DAS Pinnacle and DKC 9142 had the LAI greater than other four hybrids, which were on par. At 49 DAS, LAI was low in DKC 9042 compared to other five hybrids. Next at 63 DAS, when the LAI reaches to almost maximum, Pinnacle together with DKC 9142 and 900M Gold possessed more LAI than other three hybrids. In this season also the hybrids attained the maximum LAI at 70 DAS. From 77 DAS, and onwards LAI decreased and the hybrids did not vary except at 84 DAS.

At this stage DKC 9142, 900M Gold, DKC 9120 and Pinnacle retained significantly greater surface area of green leaf than DKC 9081 and DKC 9042.

LAI in maize that recognizes a key physiological and phenological process with minimum input requirement, an assumption that include the dominant autotrophic nature of leaf growth and the response of cell division and expansion to temperature and water deficit (Lukeba, 2013) [9]. The leaf area index is a factor that plays an important role in plant production for both quantitative and qualitative traits (Watson, 1952) [15]. During the crop growth of maize for both the seasons, among all the maize hybrids, the LAI increased dramatically from 35 DAS to 70 DAS, where the crop life cycle advances from seedling stage (V1-2) to completion of reproductive stage (V 15-16). At 70 DAS the peak leaf area was recorded in all maize hybrids during both the seasons. The maximum leaf area index for all the hybrids ranged from 4.98 to 5.75, and after the 77 DAS consistent decline in LAI was noticed in all hybrids due to senescence and assimilate translocation and arrest of leaf expansion as they were attained physiological maturity after 91 DAS. The same results were also noticed by Foster and Timmermans (2009) [7] and the same were in agreement with Shah *et al.* (2012) [13] and Chen *et al.* (2014) [6].

There were measurable variations among hybrids and other factors like morphological, physiological parameters and also environmental factors like thermal units or growing degree days (GDD) that are correlated with number and expansion and also arrangement on the stem (orientation) of the leaf that might affect the LAI (Chen *et al.*, 2014) [6].

3.2 Crop growth rate (CGR) ($\text{g m}^{-2} \text{d}^{-1}$)

The data on crop growth rate of maize hybrids during crop growth seasons of *rabi* 2016-17 and 2017-18 at every seven days interval, are presented in Table 5 and fig.3. CGR is a measure of rate of biomass production per unit ground area per unit time.

In *rabi* 2016-17, during 7 to 14 DAS, CGR was maximum in Pinnacle and DKC 9142 followed by DKC 9081, DKC 9042, DKC 9120 and minimum in 900M Gold, which showed parity with DKC 9120 and DKC 9042. During 14-21 DAS, Pinnacle, DKC 9142 and 900M Gold dominated the other hybrids. At 21-28 DAS, maximum value of CGR was noticed in DKC 9142 followed by Pinnacle, on par with DKC 9042, DKC 9120 and significantly high over DKC 9081. At 28-35 DAS, V3 and V4 had the maximum followed by Pinnacle and DKC 9142 compared to V5 and V1 which had the minimum. At 56-63 DAS along with V2 and V6, V5 had higher growth rate, followed by V4 and lower in V3 and V1. At 63-70 DAS the CGR declined, along with V2 and V6, V3 had higher growth rate, followed by V4, V1 and lower in V5. At 70-77 DAS, DKC 9142 and Pinnacle showed their significant dominance, followed by DKC 9120 and less in other three (V1, V4, V5). At 77-84 DAS, DKC 9142, still maintained higher CGR over other hybrids.

In *rabi* 2017-18, up to 21 DAS, variation in CGR among hybrids was not found. At 28-35 DAS, CGR declined; increased exponentially from 42-63 DAS and then declined. From 70 DAS, decreasing trend was noticed till the harvest. The results were in conformation with Zalba and Peinmann (1998) [18]; Sammaric *et al.* (1990) [12]; Alwal and Khan (2000) [3] and Adebo (2010) [2] noted that CGR do vary with incident solar irradiance and the higher values were found during early growth season to reproductive stage as crop age was advanced and maximum at silking stage, due to accumulation of dry matter per day upto silking was more. Sabir *et al.* (2000) [11] reported the similar results in maize that increase in CGR values in early stages due to the less vegetation and low per cent of light absorption, but rapid increase in the rate of plant growth that occurs because the level of developed leaves and thus absorption of solar radiation increases. During both the crop growth seasons at 63 DAS, maize hybrids attained maximum CGR values. The distribution and remobilization of assimilate partitioning and also duration of the crop influences the biomass accumulation and CGR of the crop.

3.3 Relative growth rate (RGR) ($\text{g g}^{-1} \text{d}^{-1}$)

Relative growth rate is a measure used to quantify the speed of crop growth, and it is a measure of rate of dry matter increase per unit dry matter per unit time.

In *rabi* 2016-17, RGR of DKC 9142 was higher than DKC 9081 and on par with other four at 14 -21 DAS (Table 6 & Fig. 4). At 28-35 DAS, together with Pinnacle, DKC 9142, the hybrids DKC 9120 and DKC 9042 showed higher RGR than other two. At 35- 42 DAS, only DKC 9142 and Pinnacle dominated the other hybrids and on par with DKC 9042. At 42-49 DAS, four hybrids V2, V6, V1 and V5 had high RGR over other two. At 56-63 DAS, three hybrids V2, V6, and V5 had high RGR and later on no differences were observed. The second season crop during *rabi* 2017-18 also exhibited the same trend by maize hybrids in RGR with minute variations. At 7-14 DAS, the RGR of Pinnacle and DKC 9142 was significantly greater than other four hybrids, but later at 14-21 DAS, Pinnacle was found to have higher RGR than 900M Gold only and on par with other hybrids. In all maize hybrids, it was noticed that during both crop growth seasons, maximum RGR values were attained at 35-42 DAS, which is an another evidence that reproductive phase shift from vegetative stage, where the reproductive tissue differentiation was initiated and were observed anatomically and later declined. Yavas and Unay (2016) [17] stated that RGR values influenced by reproductive growth stage and they were noticed that the higher RGR values were obtained at tasseling stage in maize, there after RGR values decreased after growth of blister stage (at 70 DAS) (Table 7 & Fig. 5). Alwal and Khan (2000) [3] reported that the RGR at initial stage was high and after abruptly declined with advancement of plant growth and remained more or less static between 70 DAS to 90 DAS. The results of both crop growth seasons were in conformation with the statement and findings of Yavas and Unay (2016) [17]. Similar to these results, both the crop growth seasons the same trend was observed by Hokamalipour and Darbandi (2011) [8], who stated that RGR represents the relative increase in dry matter over time, the amount of tissue structural component of plant tissue is not considered metabolic and does not share in the growth and therefore the relative growth rate decreases with time. The negative RGR values were recorded during both the crop growth seasons at harvest in

maize hybrids due to loss of the leaves at the end of the growing season.

3.4 Net assimilation rate (NAR) ($\text{mg cm}^{-2} \text{d}^{-1}$)

The production of the crop is dependent on its inherent capacity of net assimilation rate (NAR) and photosynthetic surface area (LAI). The data on net assimilation rate of maize hybrids during both crop growth seasons of *rabi* 2016-17 and 2017-18 were presented in Table 8 and 9 and depicted in figure 6 and 7. During *rabi* 2016-17, NAR of maize hybrids increased from initial vegetative stage at 7 DAS to 63 DAS and recorded maximum at 63 DAS ranged from 0.0401 to 0.0521 ($\text{mg cm}^{-2} \text{d}^{-1}$). There were no significant differences in NAR among hybrids up to 28 DAS. At 28-35 DAS, Pinnacle and DKC 9142 recorded significantly higher NAR values. Later, NAR of hybrids varied only at 49-56 and 56-63 DAS. Even though it was significant statistically, the NAR of all hybrids was on par at 49-56 DAS. At 56-63 DAS, Pinnacle and DKC 9142 possessed higher NAR than other hybrids. Next to this, DKC 9042 and DKC 9081 had more NAR than 900M Gold and DKC 9120. From 63-70 DAS there was decreasing trend till harvest in NAR of maize hybrids and negative values were recorded at harvesting stage. During *rabi* 2017-18 also the same trend was observed in maize hybrids with slight variation in NAR values. At 28-35 DAS, NAR was found more in DKC 9142 and Pinnacle than 900M Gold, DKC 9120, DKC 9042 and followed by DKC 9081. At 49-56 DAS, DKC 9142 had higher RGR superior to DKC 9120 and on par with other hybrids. At 56-63 DAS, Pinnacle and DKC 9142 possessed higher NAR than DKC 9081, DKC 9120, 900M Gold and followed by DKC 9042. During this season also from 70 DAS to harvest, no significant differences were observed among maize hybrids. The results

of both the seasons were in agreement with the findings of Alwal and Khan (2000)^[3]; Hokamalipour and Darbandi (2011)^[8]. Net assimilation rate is a measure of the rate of dry matter accumulation per unit leaf area per unit time. This attribute was also significantly higher at 63 DAS in maize hybrids particularly DKC 9142 and Pinnacle. From 70 DAS reduction in NAR values were noticed in all hybrids till harvest. Decrease in NAR from 70 DAS to harvest was due to reduction in the leaf area index, relative chlorophyll content (Table 8 and 9, and Fig. 7 and 8) in both the seasons. The similar findings were also reported by Sammerraic (1990)^[12], Zalba and Peeinemann (1998)^[18]. Veleri *et al.* (2005) reported that higher values of NAR during vegetative growth till the flowering is due to all metabolic consistency and at latter stages, a situation of restriction in photosynthesis due to mutual shade effect and competition for light and nutrients and reduction in photosynthetic area (LAI). The negative values at harvest could be due to loss of relative chlorophyll content (source activity) and reduction in source size at harvest.

3.5 Yield and Yield components

The kernel yield of six maize hybrids during *rabi* 2016-17 and 2017-18 is presented in Table 10 and Figure 8 respectively.

3.5.1 Length of the cob (cm)

Cob length of different maize hybrids is presented. Among six maize hybrids significant differences were found in both seasons during *rabi* 2016-17 and 2017-18. Among six maize hybrids, the length of the cob was observed to be highest in Pinnacle and DKC 9142 followed by DKC 9042, DKC 9120 and 900M Gold which were at par with each other. The lowest length of the cob was observed in DKC 9081.

Table 1: Leaf area index (LAI) of maize hybrids during *rabi* 2016-17

Days After Sowing	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	56 DAS	63 DAS	70 DAS	77 DAS	84 DAS	91 DAS	Harvest
GDD	114.9	220.2	334.8	434.9	541.4	632.8	730.7	829.6	929.2	1027.6	1135.7	1236.2	1338.7	1447.5
Hybrids														
900MGold (V1)	0.1	0.8	1.0	1.8	3.8	4.1	4.8	5.0	5.4	5.6	5.1	4.2	3.9	3.9
DKC 9142 (V2)	0.1	0.9	1.1	1.9	3.9	4.2	4.8	5.0	5.4	5.6	5.1	4.3	4.0	4.0
DKC 9120 (V3)	0.1	0.8	1.0	1.6	3.7	4.0	4.6	4.9	5.1	5.4	5.1	4.3	3.9	3.9
DKC 9081 (V4)	0.1	0.8	1.0	1.5	3.6	4.1	4.5	4.9	5.1	5.3	5.0	4.1	3.9	3.9
DKC 9042 (V5)	0.1	0.7	1.1	1.8	3.5	4.2	4.5	5.0	5.1	5.4	5.0	4.2	4.0	4.0
Pinnacle (V6)	0.1	0.8	1.3	2.0	3.9	4.4	4.9	5.0	5.4	5.7	5.1	4.3	4.0	4.0
SEm±	0.007	0.03	0.05	0.11	0.15	0.13	0.16	0.11	0.19	0.19	0.10	0.15	0.08	0.08
CD (p=0.05)	0.01	0.06	0.11	0.23	0.32	0.28	0.35	0.24	NS	NS	0.28	NS	NS	NS
CV%	1.75	5.73	7.30	8.97	5.89	4.46	4.99	3.32	5.19	5.01	2.99	5.32	3.20	3.20

Table 2: Leaf area index (LAI) of maize hybrids during *rabi* 2017-18

Days After Sowing	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	56 DAS	63 DAS	70 DAS	77 DAS	84 DAS	91 DAS	Harvest
GDD	141.6	253.4	352.5	457.3	557.7	653.6	748.5	838.6	942.5	1032.7	1130.7	1226.8	1334.9	1424.8
Hybrids														
900MGold (V1)	0.05	0.8	1.0	2.2	3.5	4.2	5.2	5.3	5.6	5.6	5.1	4.9	3.8	3.8
DKC 9142 (V2)	0.05	0.9	1.1	2.7	3.8	4.4	5.3	5.5	5.7	5.7	5.2	4.9	3.8	3.8
DKC 9120 (V3)	0.04	0.9	1.0	2.4	3.6	4.1	5.2	5.3	5.4	5.5	5.1	4.8	3.8	3.8
DKC 9081 (V4)	0.05	0.8	1.0	2.2	3.5	4.0	5.1	5.3	5.4	5.4	5.1	4.2	3.6	3.6
DKC 9042 (V5)	0.05	0.8	1.0	2.2	3.6	4.1	5.0	5.2	5.3	5.3	5.0	4.3	3.7	3.7
Pinnacle (V6)	0.05	0.9	1.2	2.5	4.0	4.4	5.4	5.6	5.8	5.8	5.1	4.7	3.8	3.8
SEm±	0.003	0.02	0.05	0.13	0.15	0.11	0.15	0.09	0.12	0.09	0.10	0.26	0.12	0.12
CD (p=0.05)	0.007	0.04	0.10	0.28	0.32	0.24	0.32	0.21	0.26	NS	0.23	0.57	NS	NS
CV%	10.06	3.78	6.88	8.12	5.94	3.89	4.16	2.62	3.15	2.67	3.05	8.05	4.53	4.53

Table 3: Crop growth rate of maize hybrids during *rabi* 2016-17

Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	220.2	334.8	434.9	541.4	632.8	730.7	829.6	929.2	1027.6	1135.7	1236.2	1338.7	1447.5
Hybrids													
900MGold (V1)	1.06	2.50	3.70	1.24	3.47	47.93	93.02	180.92	58.32	33.92	2.88	1.38	1.30
DKC 9142 (V2)	1.23	2.65	4.14	1.59	3.72	48.96	94.30	200.32	65.48	34.90	4.35	1.35	-0.35
DKC 9120 (V3)	1.17	2.38	3.21	1.92	4.07	47.43	86.38	188.07	63.86	34.12	1.39	0.39	-0.21
DKC 9081 (V4)	1.20	2.36	2.73	1.92	3.66	46.75	84.76	191.24	57.12	32.29	1.98	1.98	-0.25
DKC 9042 (V5)	1.19	2.42	3.67	1.40	3.30	49.15	84.64	199.58	49.59	33.67	3.16	1.96	-1.76
Pinnacle (V6)	1.23	2.66	4.02	1.65	3.63	48.59	97.81	202.94	64.67	36.49	3.17	1.17	-0.90
SEm±	0.02	0.41	0.06	0.14	0.36	2.72	1.36	2.27	2.47	0.80	0.33	0.33	0.13
CD(p=0.05)	0.14	0.08	1.15	0.30	NS	1.53	2.91	9.84	5.24	1.72	0.72	NS	NS
CV%	3.93	4.59	7.03	4.04	2.06	1.16	12.07	7.66	4.86	2.57	1.57	1.51	0.87

Table 4: Crop growth rate of maize hybrids during *rabi* 2017-18

Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	253.4	352.5	457.3	557.7	653.6	748.5	838.6	942.5	1032.7	1130.7	1226.8	1334.9	1424.8
Hybrids													
900MGold (V1)	1.77	1.53	3.71	1.31	3.71	50.59	90.26	185.69	51.18	41.66	7.06	1.14	1.10
DKC 9142 (V2)	2.16	1.73	4.07	1.79	4.15	52.05	98.78	196.01	70.23	43.24	9.44	4.36	1.36
DKC 9120 (V3)	2.00	1.53	3.25	1.61	3.68	48.88	86.49	182.91	47.93	31.34	6.64	1.58	-1.24
DKC 9081 (V4)	1.96	1.55	3.25	1.66	4.01	47.32	81.34	181.72	48.01	32.53	5.55	1.98	-1.08
DKC 9042 (V5)	1.97	1.60	3.61	1.46	3.77	48.43	88.48	189.74	55.94	34.12	4.98	2.38	1.31
Pinnacle (V6)	2.26	1.55	4.45	1.63	4.09	51.69	99.19	192.85	74.19	42.45	7.93	0.39	-0.01
SEm±	0.02	0.74	0.01	0.14	0.36	0.72	1.86	2.56	2.37	0.80	0.33	2.52	0.33
CD(p=0.05)	NS	NS	1.14	0.30	NS	2.13	5.01	9.54	8.36	2.36	1.02	NS	NS
CV%	3.97	3.63	2.07	4.04	11.06	2.16	8.07	11.01	10.98	6.57	9.57	1.11	1.69

Table 5: Relative growth rate of maize hybrids during *rabi* 2016-17

Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	220.2	334.8	434.9	541.4	632.8	730.7	829.6	929.2	1027.6	1135.7	1236.2	1338.7	1447.5
Hybrids													
900MGold (V1)	0.131	0.039	0.021	0.046	0.224	0.133	0.111	0.023	0.016	0.014	0.004	0.001	0.001
DKC 9142 (V2)	0.126	0.040	0.024	0.054	0.244	0.139	0.121	0.025	0.018	0.015	0.006	0.002	0.002
DKC 9120 (V3)	0.121	0.035	0.023	0.049	0.216	0.126	0.117	0.022	0.015	0.013	0.005	0.001	0.001
DKC 9081 (V4)	0.119	0.031	0.021	0.041	0.219	0.126	0.114	0.019	0.013	0.013	0.003	0.001	0.001
DKC 9042 (V5)	0.121	0.038	0.023	0.049	0.229	0.129	0.115	0.024	0.015	0.014	0.004	0.001	0.001
Pinnacle (V6)	0.126	0.039	0.025	0.052	0.249	0.138	0.123	0.025	0.017	0.014	0.005	0.002	0.002
SEm±	0.001	0.003	0.004	0.007	0.009	0.005	0.004	0.005	0.008	0.001	0.001	0.001	0.002
CD(p=0.05)	NS	0.009	NS	0.008	0.0205	0.0131	NS	0.0050	NS	NS	NS	NS	NS
CV%	1.667	4.032	2.564	4.566	6.384	3.276	6.253	5.074	3.405	2.401	3.906	4.238	2.250

Table 6: Relative growth rate of maize hybrids during *rabi* 2017-18

Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	253.4	352.5	457.3	557.7	653.6	748.5	838.6	942.5	1032.7	1130.7	1226.8	1334.9	1424.8
Hybrids													
900MGold (V1)	0.141	0.044	0.025	0.049	0.225	0.137	0.115	0.025	0.017	0.015	0.005	0.002	0.001
DKC 9142 (V2)	0.153	0.052	0.027	0.052	0.246	0.141	0.119	0.028	0.019	0.016	0.008	0.003	0.002
DKC 9120 (V3)	0.137	0.046	0.023	0.050	0.218	0.128	0.114	0.024	0.017	0.014	0.004	0.001	0.001
DKC 9081 (V4)	0.139	0.048	0.022	0.046	0.220	0.127	0.116	0.026	0.016	0.013	0.006	0.002	0.001
DKC 9042 (V5)	0.140	0.049	0.023	0.049	0.228	0.129	0.117	0.023	0.017	0.015	0.007	0.001	0.002
Pinnacle (V6)	0.157	0.054	0.025	0.053	0.247	0.140	0.120	0.029	0.019	0.017	0.008	0.003	0.002
SEm±	0.001	0.003	0.004	0.007	0.009	0.005	0.004	0.005	0.008	0.001	0.001	0.001	0.002
CD(p=0.05)	0.014	0.009	NS	0.007	0.0200	0.0101	0.0025	0.0029	NS	NS	NS	NS	NS
CV%	1.667	4.032	2.564	4.566	9.364	5.236	3.265	7.084	5.365	2.004	3.546	3.698	4.310

Table 7: Net assimilation rate of maize hybrids during *rabi* 2016-17

Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	220.2	334.8	434.9	541.4	632.8	730.7	829.6	929.2	1027.6	1135.7	1236.2	1338.7	1447.5
Hybrids													
900MGold (V1)	0.0022	0.0022	0.0039	0.0075	0.0084	0.0127	0.0226	0.0401	0.0301	0.0162	0.0108	0.0050	-0.0010

DKC 9142 (V2)	0.0024	0.0026	0.0043	0.0093	0.0098	0.0134	0.0231	0.0510	0.0392	0.0189	0.0125	0.0056	0.0015
DKC 9120 (V3)	0.0021	0.0021	0.0036	0.0074	0.0083	0.0129	0.0210	0.0402	0.0298	0.0156	0.0105	0.0048	0.0010
DKC 9081 (V4)	0.0022	0.0022	0.0035	0.0081	0.0081	0.0130	0.0211	0.0431	0.0301	0.0145	0.0124	0.0049	-0.0011
DKC 9042 (V5)	0.0021	0.0024	0.0038	0.0078	0.0090	0.0132	0.0220	0.0452	0.0297	0.0169	0.0124	0.0047	0.0012
Pinnacle (V6)	0.0025	0.0025	0.0042	0.0098	0.0097	0.0135	0.0229	0.0521	0.0367	0.0187	0.0125	0.0054	0.0014
SEm±	0.0018	0.003	0.004	0.007	0.009	0.005	0.004	0.005	0.008	0.001	0.001	0.001	-0.0021
CD (p=0.05)	NS	NS	NS	0.001	NS	NS	0.0025	0.0029	NS	NS	NS	NS	NS
CV%	1.667	1.089	2.004	1.566	1.364	1.236	3.265	1.084	2.365	2.054	1.546	1.698	1.310

Table 8: Net assimilation rate of maize hybrids during *rabi* 2017-18

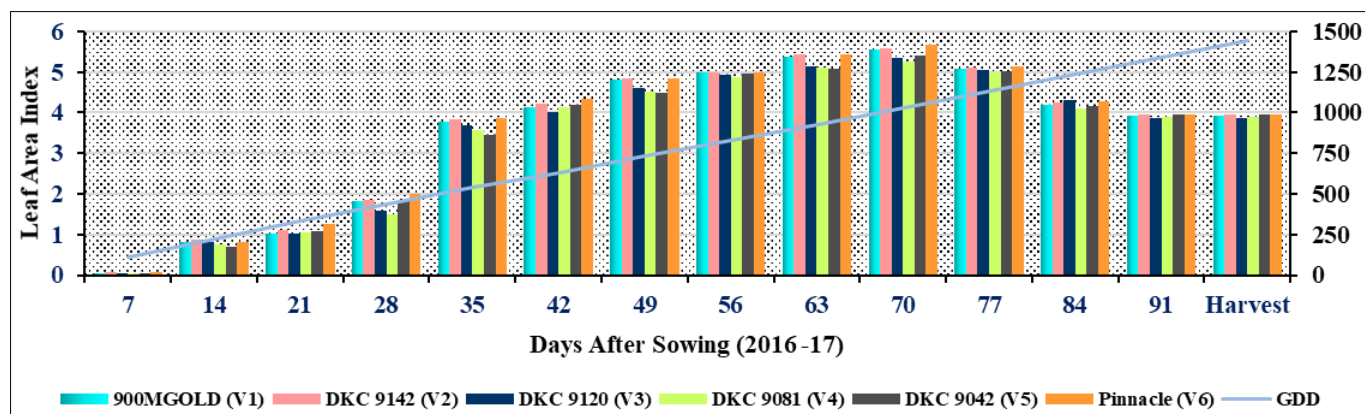
Days After Sowing	7-14 DAS	15-21 DAS	22-28 DAS	29-35 DAS	36-42 DAS	43-49 DAS	50-56 DAS	57-63 DAS	64-70 DAS	71-77 DAS	72-84 DAS	85-91 DAS	Harvest
GDD	253.4	352.5	457.3	557.7	653.6	748.5	838.6	942.5	1032.7	1130.7	1226.8	1334.9	1424.8
Hybrid													
900MGold (V1)	0.0028	0.0021	0.0040	0.0077	0.0085	0.0124	0.0227	0.0401	0.0307	0.0162	0.0118	0.0051	-0.0011
DKC 9142 (V2)	0.0029	0.0026	0.0043	0.0096	0.0097	0.0131	0.0237	0.0510	0.0398	0.0189	0.0125	0.0056	0.0014
DKC 9120 (V3)	0.0021	0.0023	0.0037	0.0074	0.0084	0.0125	0.0215	0.0402	0.0299	0.0156	0.0115	0.0046	-0.0010
DKC 9081 (V4)	0.0022	0.0026	0.0036	0.0082	0.0082	0.0128	0.0217	0.0431	0.0309	0.0145	0.0123	0.0049	0.0011
DKC 9042 (V5)	0.0021	0.0027	0.0038	0.0079	0.0091	0.0126	0.0228	0.0452	0.0299	0.0169	0.0124	0.0047	0.0012
Pinnacle (V6)	0.0025	0.0027	0.0044	0.0098	0.0091	0.0133	0.0229	0.0521	0.0369	0.0187	0.0125	0.0055	-0.0014
SEm±	0.001	0.003	0.004	0.007	0.009	0.005	0.004	0.005	0.008	0.001	0.0056	0.0023	-0.0011
CD(p=0.05)	NS	NS	NS	0.008	NS	NS	0.0021	0.0034	NS	NS	NS	NS	NS
CV%	1.667	1.032	2.564	1.566	1.364	2.236	1.245	2.064	1.205	1.504	1.546	1.698	0.840

Table 9: Yield and Yield Components of Maize Hybrids during *rabi* 2016-17

Hybrid	Length of the Cob (cm)	No. of rows per Cob	Kernel per Row	100 seed weight (g)	Total kernel yield (Kg ha ⁻¹)
900MGold (V1)	15.26	16.00	33.50	17.21	8522
DKC 9142 (V2)	16.11	16.00	35.00	20.11	9244
DKC 9120 (V3)	15.38	14.00	33.50	16.50	8056
DKC 9081 (V4)	15.06	14.00	33.60	17.00	8449
DKC 9042 (V5)	15.56	14.00	33.50	16.50	7985
Pinnacle (V6)	16.16	16.00	37.00	20.00	9641
SEm±	0.43	0.69	1.47	0.56	501.52
CD (p=0.05)	0.92	1.49	3.13	1.90	1511.75
CV%	3.94	6.59	6.12	4.65	11.65

Table 10: Yield and Yield Components of Maize Hybrids during *rabi* 2017-18

Hybrid	Length of the Cob (cm)	No. of rows per Cob	Kernel per Row	100 seed weight (g)	Total kernel yield (Kg ha ⁻¹)
900MGold (V1)	15.55	16.00	33.54	17.89	8829
DKC 9142 (V2)	16.71	16.00	35.14	20.25	9422
DKC 9120 (V3)	15.45	14.00	33.52	17.07	8256
DKC 9081 (V4)	15.13	14.00	32.92	17.79	8349
DKC 9042 (V5)	15.61	14.00	32.90	16.89	8014
Pinnacle (V6)	16.67	16.00	36.22	20.69	9642
SEm±	0.35	0.92	1.19	0.67	529.98
CD (p=0.05)	0.94	1.03	3.74	1.99	1517.55
CV%	3.85	6.21	6.25	4.45	12.08

**Fig 1:** The data on leaf area index measured at seven days interval from seedling to harvest were presented

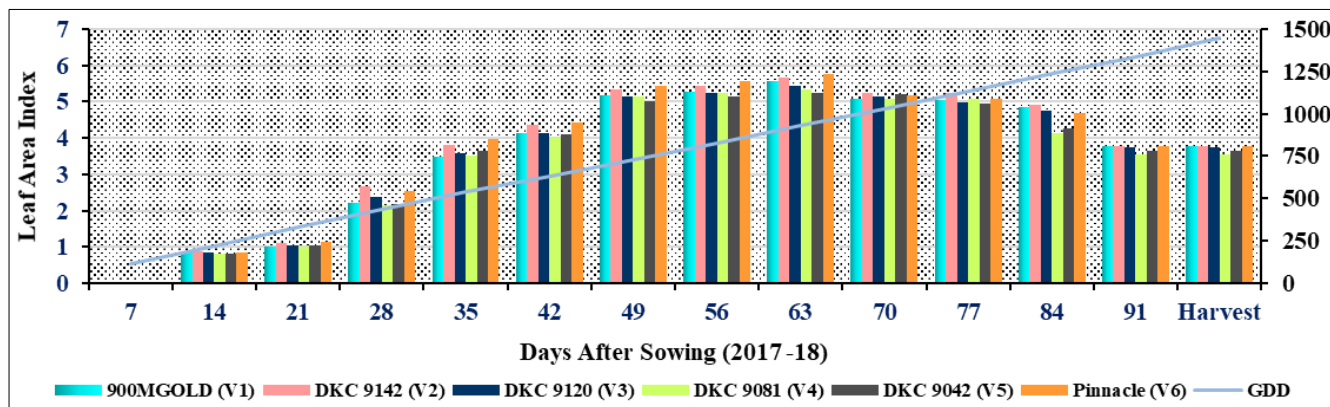


Fig 2: During rabi 2017-18, the differences among hybrids in LAI at 7 DAS were negligible

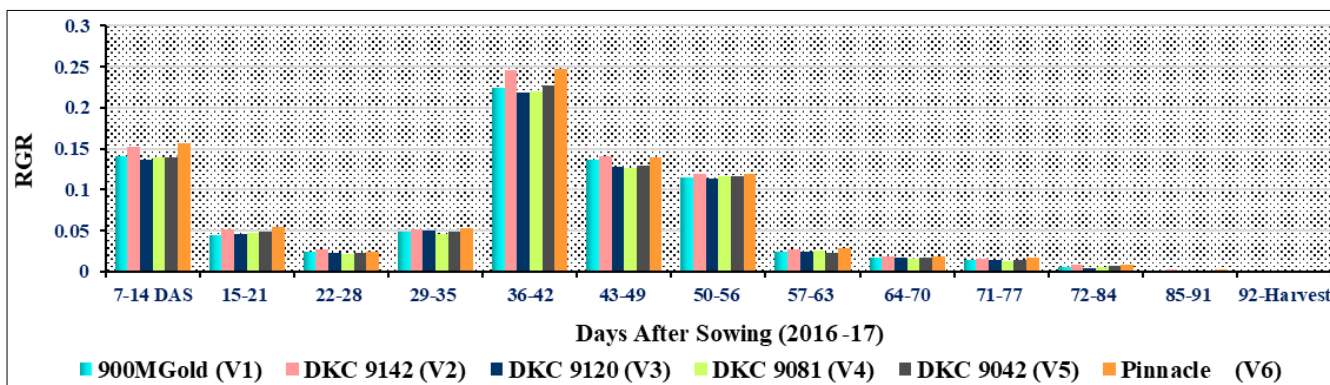


Fig 3: The data on crop growth rate of maize hybrids during crop growth seasons of rabi 2016-17

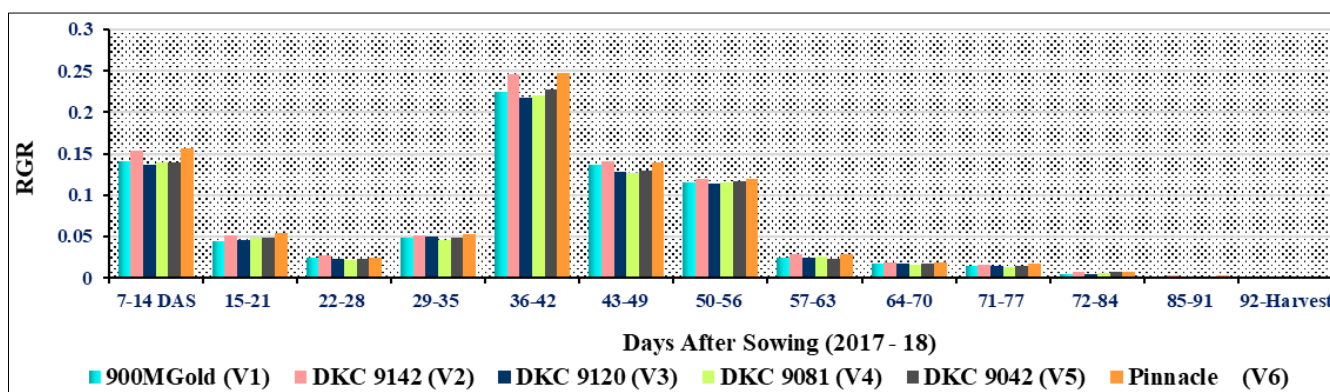


Fig 4: In rabi 2016-17, RGR of DKC 9142 was higher than DKC 9081 and on par with other four at 14 -21 DAS

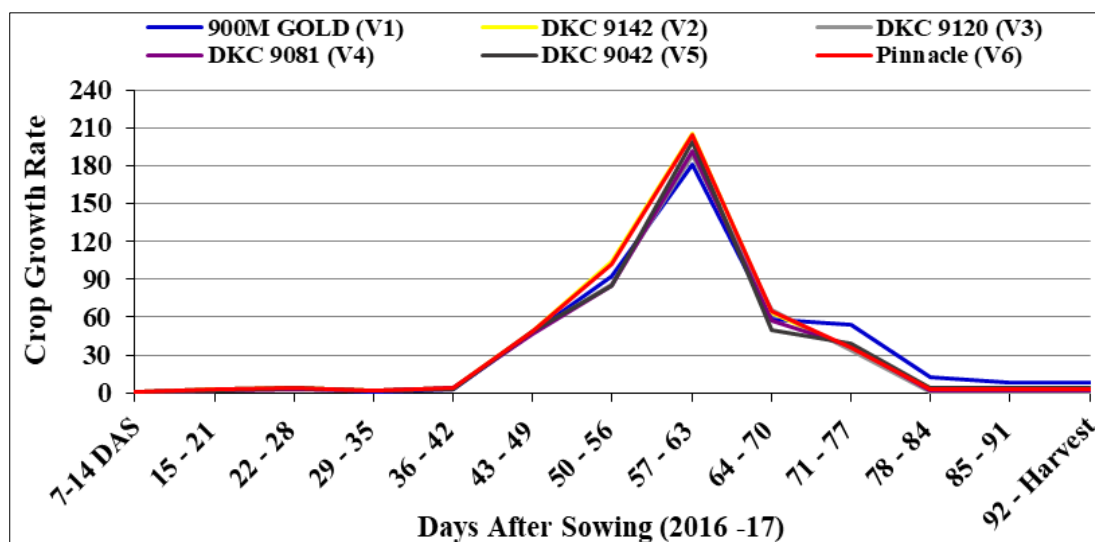


Fig 5: The higher RGR values were obtained at tasseling stage in maize, there after RGR values decreased after growth of blister stage (at 70 DAS)

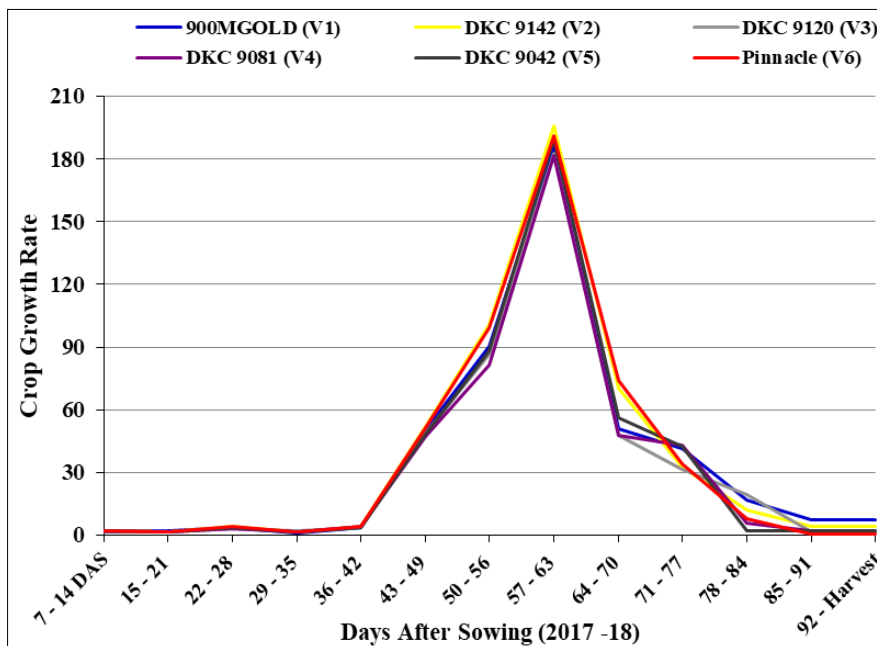


Fig 6: The data on net assimilation rate of maize hybrids during both crop growth seasons of rabi 2016-17 and 2017-18

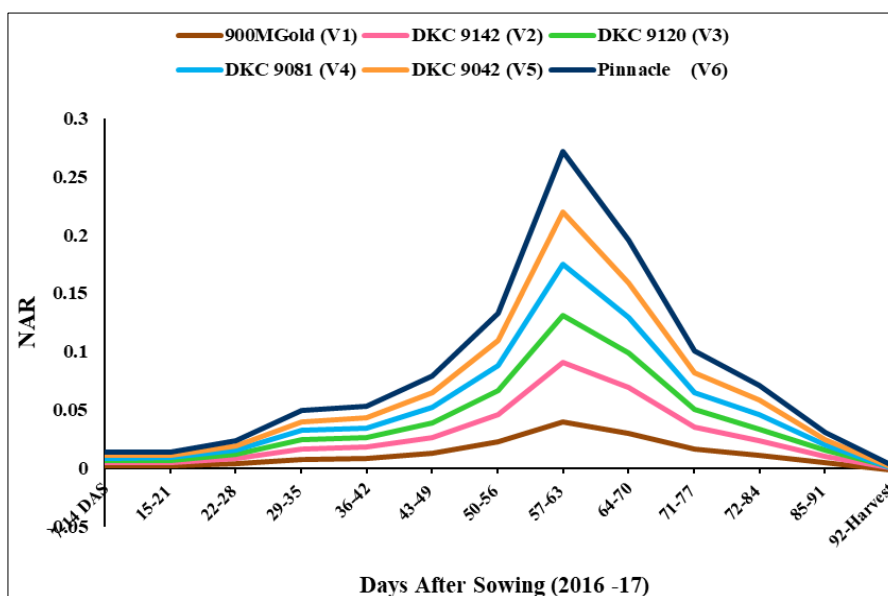


Fig 7: Decrease in NAR from 70 DAS to harvest was due to reduction in the leaf area index, relative chlorophyll

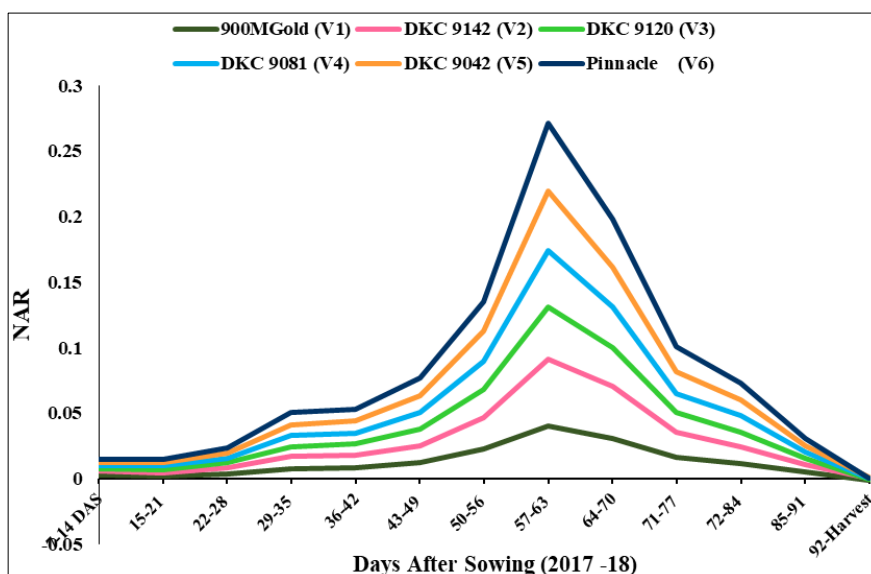


Fig 8: The kernel yield of six maize hybrids during rabi 2016-17 and 2017-18

3.5.2 Number of rows per cob

In both crop growth seasons of *rabi* 2016-17 and 17-18; Pinnacle, DKC 9142 and 900M Gold recorded significantly more number of rows per cob compared to other three hybrids.

3.5.3 Number of kernels per row

Number of kernels per row during *rabi* 2016-17, pinnacle and DKC 9142 recorded significantly more number of kernel per row. During *rabi* 2017-18, Pinnacle and DKC 9142 recorded more number of kernels per row followed by 900M Gold, DKC 9120, DKC 9081 and DKC 9042.

3.5.6 Test weight of 100 seed (g)

During the crop growth period of *rabi* 2016-17, pinnacle and DKC 9142 recorded significantly higher test weight for 100 seed, and the consequent growth season during *rabi* 2017-18, along with Pinnacle and DKC 9142, 900M Gold and DKC 9180 are also elevated as significant hybrids in 100 seed test weight.

3.5.7 Total kernel yield (Kg ha⁻¹)

Significant differences were observed between six maize hybrids with regards to kernel yield. During *rabi* 2016-17, Pinnacle (9641) and DKC 9142 (9243) recorded significantly higher kernel yield followed by 900M Gold (8522), DKC 9081 (8449) and DKC 4120 (8056), DKC 9042 (7705) recorded significantly less yield.

The same trend was shown with regard to kernel yield during *rabi* 2017-18 also in six maize hybrids. Pinnacle (9642) and DKC 9142 (94422) were recorded significantly higher kernel yield followed by other four hybrids 900M Gold (8829), DKC 9081 (8349), DKC 9120 (8256) and DKC 9042 (8134). However, the yield attributes like length of the cob, number of rows for cob, kernel for row per cob and 100 seed weight also influences the seed yield. A slight increase in kernel yield in six maize hybrid were observed during *rabi* 2017-18, where respective GDDs of growth season also increased.

Both the growing seasons of *rabi* 2016-17 and 2017-18, the physiological parameters like CGR, RGR, NAR and LAI were positively related to the respective maize hybrids, as the same findings were confirmed with Williams (1946)^[16].

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