Effect of delayed sowing on quality and yield attributes of different Rice (*Oryza sativa* L.) genotypes

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ABSTRACT : To examine the effect of late sowing (after 15 days of normal) on grain quality and yield, a field experiment was conducted during the kharif season of year 2011 with six rice genotypes namely, hybrids KRH-2, PA-6129, PHB-71 and inbreds AK-DHAN, NDR-359, VARADHAN. Yield parameters (number of primary and secondary branches per panicle, biological yield, economic yield and harvest index) and quality parameters (total carbohydrate and amylose) were studied under both the conditions. After critical analysis of all the parameters, it was observed that except hybrids KRH-2 and PHB-71 (6-10 per cent reduction) all the genotypes showed 17-28 per cent enhancement in biological yield under late sown conditions. However, all the rice genotypes except PA-6129 (19.9 per cent enhancement) showed decline (6-68 per cent) in economical yield under late sown condition when compared to early sown. Delayed sowing of all the genotypes also reduced total carbohydrate in the range of 15-55 per cent as well as amylose content in the range of 4-18 per cent. However, PA-6129 showed lowest reduction in amylose content and performed better in late sown condition. Study suggests that PA-6129 was comparatively less sensitive to photoperiod as compared to other hybrids and inbreds.

Key words: Amylose, delayed sowing, grain yield, *Oryza sativa*

Rice (*Oryza sativa* L.) is the most important and largely irrigated food crop in the world. It is basically a crop of humid tropics, but it varies widely in physiological adaptability, hence grown successfully both in temperate and tropical conditions up to an altitude of about 2250 m above mean sea level. It is normally grown where the rainfall during the crop season is around 650 mm or more. Under sub-tropical conditions, it is grown during Kharif season where the temperature at sowing is higher (30˚C- 35˚C) and slowly declines until maturity. Temperature beyond 30˚C with high light intensity affects fertilization and grain filling. Moderately high temperature is congenial for vegetative growth, whereas the blossoming stage benefits from slightly lower temperature (20°C- 25°C). The increase in both frequency and intensity of high temperature, along with its large variability, is emerging as a potential threat to the sustainability of rice production (Jagadish *et al*., 2010).

The sowing and transplanting of rice in the optimum period of time is very important to achieve high quality and grain yield. However, optimum rice planting dates are regional and vary with location and genotypes. Rice plants require a particular temperature for its phenological affair such as panicle initiation, flowering, panicle exertion and maturity (Yoshida, 1981). Optimum planting dates are thus required to provide optimum temperature and light conditions to the crop during different growth stages. Early sowing is usually beneficial to the rice crop than the late sowing because the late sown crop faces low temperature effect during early growth phases (mean minimum temperature) and high temperature stress (37.2˚C) coupled with high evaporation rates during terminal phases. Thus, establishment and subsequent growth get affected by temperature, which result in lesser yields at late sown condition (Anjani, 2012).

High or low temperatures at meiosis stage affect the seed-setting rates. With the increase of temperature and its duration, the seed-setting rate decreases gradually. High temperature during meiosis influences the development of anther and pollen grains, thereby reducing anther dehiscence and pollen fertility rate and yield components such as number of spikelet per panicle, seed-setting rate, 1000-grain weight, and grain yield (Cao *et al.,* 2008). The generalized relationship between temperature and length of time required to complete development is curvilinear, indicating that time required for plant development is lengthened below and above optimum temperatures (Anonymous, 2009).

The impact of increased temperature has an accumulative effect on the later phases of plant development. It changes the vegetative, ripening and grain-filling phase and ultimately affects the grain quality of the rice. It is well known that rice quality is basically determined by the presence of starch (appropriate ratio of amylopectin and amylose). In general, rice grains contain approximately 90 per cent carbohydrate (starch), 2 per cent lipids, 6–8 per cent proteins, and 1 per cent mineral content in wild rice (Jang *et al.,* 2009). The amylose content in rice usually ranges from 17-23 per cent. Rice with a high amylose content exhibits high volume expansion and a high degree of flakiness. High amylose grains cook dry and become hard upon cooking. So, the intermediate amylose in rice is preferred in most rice growing areas.

Global warming is a serious threat worldwide, reducing the world's agricultural gross domestic product by up to 16 per cent by 2020. Simultaneously, the prices of agricultural commodities are predicted to increase by 40 per cent with a 3°C increase in global temperature (Intergovernmental Panel on Climate Change, 2007, Easterling *et al.,* 2007). Due to global warming, weather patterns are changing and monsoon rainfall is grossly uneven. Indian monsoon during the last decade is not commencing at its predicted time. The overall rice yield variability due to climate variability over the last three decades was estimated by Ray *et al.* (2015), and it was concluded that approximately 53% of rice harvesting regions experiences the influence of climate variability on yield at the rate of about 0.1 t/hm^2 per year and approximately 32% of rice yield variability is explained by year-to-year global climate variability. So, it is becoming a serious issue to overcome this problem as well as minimize the yield loss due to untimely rainfall. Therefore, the present study will give some insights in the selection of rice hybrids and inbreds which could grow better under variant photoperiod, temperature and late monsoon rainfall, with minimum reduction in grain yield and quality.

MATERIALS AND METHODS

The present investigation was carried out during Kharif season of year 2011 at Norman Borolaug Crop Research Center, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India. Geographically, the site lies in Tarai plains about 30 km southwards of foothills of Shivalik range of the Himalayas at 29° N latitude, 79° 29' E longitude and at an altitude of 243.8 meter above the mean sea level. The seeds of six rice genotypes, namely, hybrids KRH-2, PA-6129, PHB-71 and inbreds AK-DHAN, NDR-359, VARADHAN were obtained from the Directorate of Rice Research, Rajendranagar, Hyderabad.

Field Preparation

Seeds were raised in nursery by dry bed method. The seeds beds were flooded on alternate days. Transplanting was done 21 days after sowing. A day before transplanting, the field was flooded with water and puddled on the following day. The field was divided into six strips, three strips for early sown seedlings (normal) and three for late sown (15 days after normal sowing) to fulfill the requirement of proper randomization. Each strip was divided into six sub plots of size 2.25 m^2 each and spacing of 1.5m x 0.5m between subplots. Within each plot row spacing of 20cm x 20cm was maintained. The experiment was carried out with two treatments and three replications of each in a split plot design.

Dates of nursery sowing in early (normal) and late sown set of genotypes were 07-06-2011 and 22-06-2011 respectively. Transplanting in both early and late set was done 21 days after sowing i.e. 28-06-2011 and 13-07-2011 respectively.

Yield attributes

Each plant was uprooted from the ground level at maturity and after drying, the weight of intact plant was determined before thrashing and biological yield was expressed in g m^{-2}. Economic yield from each replication after harvesting was recorded and finally expressed as g m^{-2}. The harvest index was calculated using the following formula:

$$\text{Harvest index (per cent)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Biochemical analysis

Total carbohydrate content was estimated in rice grain by using the anthrone method (Hodge and Hofreiter, 1962). However, amylose content was estimated in rice grains by using the method described by McCready and Owens, 1950.

Statistical Analysis

The statistical analysis of data for all the parameters was carried out with analysis of variance for split plot design. The means were tested at $P > 0.05$ using a STPR software designed at Department of Mathematics, Statistics and Computer Science, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture and Technology, Pantnagar, India.

RESULTS AND DISCUSSION

Grain yield of any crop depends upon various components such as effective tillers, number of branches per panicle, their fertility and grain weight etc. However, all these yield components are affected by various environmental factors like soil texture, temperature and sowing conditions. Delayed sowing affects different growth stages of crops and reduces growth related parameters, due to fluctuations in temperature and light intensity. High temperature at anthesis substantially affects grain filling duration, its rate and ultimately reduces grain yield (Ram *et al.,* 2014).

Rice crop is very sensitive to sowing conditions. In the present study, the influence of normal and late sown conditions on the number of primary and secondary branches per panicle, biological yield and economical yield was recorded in all the six rice genotypes (Table 1 and 2). Among normal and late sown genotypes, the number of primary and secondary branches per panicle was increased in all the genotypes except KRH-2 and PHB-71 during late sown conditions, when compared with early sown conditions. These genotypes showed 2-12 per cent reduction in number of branches per panicle, however, all the other genotypes showed 15-95 per cent enhancement in the number of primary and secondary branches per panicle during late sown conditions. The reproductive stage is highly sensitive to high temperatures. During normal sowing, the optimal temperature appears to shift from high to low as growth advances from the vegetative to the reproductive stages. Hence, the number of branches per panicle increases when the temperature drops. Number of branches per panicle is also affected by climatic conditions such as solar radiation and temperature. Shading or low light during the reproductive stage has a pronounced effect on spikelet number (Yoshida, 1981). When the sowing date of different rice varieties was delayed, the ratio of number of primary branches to number of secondary branches, number of branches per primary and secondary branch, grain number per primary and secondary branch were decreased (Zhipeng *et al.,* 2015).

In the present study, biological yield was increased in all the genotypes except KRH-2 and PHB-71 during late sown conditions when compared with early sown genotypes. These genotypes showed 6-10 per cent reduction in biological yield however all other genotypes performed better and showed 17-28 per cent enhancement in the biological yield. In contrast to biological yield, economic yield decreased under late sown conditions. All the rice genotypes except PA-6129 showed decline in economical yield under late sown conditions when compared to normal sown genotypes. Only PA-6129 showed 19.9 per cent enhancement in economic yield however a great variation in reduction (about 6-68 per cent) was observed in all other late sown genotypes when compared with normal sown. Results showed that in most of the genotypes grain yield decreased as the sowing date was delayed. This might be due to the long sunshine hours during normal sown condition, as it is important for production, assimilation and translocation of photosynthates. As rice is a photo sensitive plant, reduced sunshine hours ultimately reduced the grain yield. That is why; late sown rice genotypes had low grain yield. Shah and Bhurer (2005) and Bashir *et al.* (2010) reported that more number of

Table 1: Number of primary and secondary branches per panicle of different genotypes of rice under normal and late sown conditions (± indicates SE)

Variety	Number of primary branches per panicle		Number of secondary branches per panicle	
	Normal sown	Late sown	Normal sown	Late sown
KRH-2	13.1±0.58	12.4±0.48	48.3±4.66	45.4±0.61
PA-6129	10.7±0.44	12.4±0.48	39.5±3.05	47.5±2.73
PHB-71	13.2±0.58	11.6±0.19	48.8±1.39	47.8±1.44
AK-DHAN	13.8±0.67	17.0±0.96	34.5±2.72	67.6±3.52
NDR-359	11.6±0.19	14.2±0.98	38.1±1.31	47.6±6.93
VARADHAN	13.1±0.29	13.7±0.96	43.8±1.96	52.1±2.48
Mean	12.6	13.5	42.2	51.3
	Treatment (T)	Variety (V)	Treatment (T)	Variety (V)
S.Em. ±	0.264	0.458	1.289	2.234
CD at 5 %	0.776	1.344	3.783	6.552

filled grains per panicle was visualized in the early seeding and declined gradually in the successive seeding dates. Abou Khalifa and El-Rewainy (2012), showed that early sown rice varieties, gave the highest value on panicle length (cm), number of grains/panicle,1000-grains weight (g) and grains yield (t/ha) as compared to late sown varieties.

Previous work reported that increase in economic yield under early sown conditions was attributed to the increased sunshine hours, as it is important for proper growth of tillers, large number of grains per panicles and better grain filling (Chopra *et al.,* 1998). Excessive rainfall is also associated with low sunlight and it creates hindrance in photosynthesis, leading to decreased grain yield under late sown conditions (Yoshida, 1981). In one study, decreased grain yield under low light was mainly attributed to spikelet sterility and less number of grains per panicle. Regardless of cultivar and growth phase, the magnitude of reduction in growth, yield, and yield parameters was greater under decreased light intensity (Singh, 2005).

Plant exposure to low radiation at ripening caused high spikelet sterility (Trivedi and Kwatra, 1983). Variation in night temperatures may also affect the number and fertility of spikelets. When high night temperature coincides with critical developmental stages such as flowering, there would be improper pollination and a reduction in the number of pollen germinated on the stigma, which ultimately would lead to spikelet sterility and low yield. These effects are similar to those caused by high day temperatures, indicating that increased day or night temperature at the reproductive stage could lead to increased sterility (Mohammed and Tarpley, 2009). Further, it is reported that the transplanting date had a significant effect on total number of sterile spikelet per panicle, total tiller number, panicle number per plant per m^2 and finally the yield of rice crop (Faghani *et al.,* 2011). In another study, thirty diverse genotypes of chickpea were sown at different dates and the G × E interaction was found significant for harvest index, total seeds per pod and effective pods per plant, hundred seed weight, biological yield and seed yield (Shukla *et al.,* 2014).

High temperature limits photosynthetic production capability of rice, which mainly originates from the higher reducing rate of leaf photosynthetic velocity. Sterility of pollens due to high temperatures is an important factor for reduction of grain yield (Xie *et al.,* 2011). In an study with different rice accessions which were sown on five different sowing dates (16^{th} april, 1st May, 16 may, 1 June and 16 june), it was found that first two sowing dates had relatively higher temperature during reproductive phase, thus produced minimum yield compared with three later sowing dates (Safdar *et al*., 2013). Not only the high temperatures, but cool temperatures might be a factor to slow down the rate of development of crops leading to prolonged growth duration (Sinclair and Bai, 1997). Prolonged growth durations are associated with lower minimum temperatures. Thus, the sowing dates should be adjusted in such a way that its reproductive growth phase does not coincide with high temperature stress as it results in lower number of grains per panicle, resulting in lower grain yield (Safdar *et al*., 2008, 2013)

A common way of examining rice grain yield is to measure the total dry weight and grain yield, and then compute the ratio of these two (harvest index or HI). The harvest index is a measure of the economically useful fraction of the biological yield. In the present study, harvest index was found to be significantly differed in normal and late sown conditions as presented in Table 2.

Table 2: Biological yield (g/m^2), Economic yield (g/m^2) and Harvest index (per cent) of different genotypes of rice under normal and late sown conditions (± indicates SE)

Variety	Biological yield (g/m^2)		Economic yield (g/m^2)		Harvest Index (per cent)	
	Normal sown	Late sown	Normal sown	Late sown	Normal sown	Late sown
KRH-2	1715.33±73.68	1615.00±13.07	822.66±17.13	676.00±16.62	48.14±1.01	41.90±2.97
PA-6129	1301.00±97.07	1800.00±75.10	516.00±38.97	644.33±26.35	40.57±10.09	36.43±3.66
PHB-71	1614.66±118.6	1458.33±54.34	735.16±37.90	689.16±48.53	45.68±1.16	47.30±0.45
AK-DHAN	1474.33±97.91	1897.66±104.2	650.66±17.26	485.33±11.86	44.31±0.99	25.57±0.42
NDR-359	1505.00±64.25	1834.00±83.50	708.33±32.76	421.16±24.29	46.99±0.36	22.70±1.39
VARADHAN	1465.00±76.50	1799.33±51.13	677.66±17.85	511.83±38.71	46.49±1.39	28.29±1.47
Mean	1512.55	1734.05	685.08	571.30	45.36	33.70
	Treatment (T)	Variety (V)	Treatment (T)	Variety (V)	Treatment (T)	Variety (V)
S.Em. ±	33.337	57.742	12.487	21.628	1.374	2.379
CD at 5 %	97.774	169.350	36.623	63.433	4.029	6.980

When we compare the harvest index of all the genotypes, a great reduction (about 40-60 per cent) in AK-DHAN, NDR-359 and VARADAHAN was found under late sown conditions however KRH-2 and PA-6129 reduced their HI with only 12.9 and 10.2 per cent, respectively, when compared with normal sown genotypes. Only the late shown genotype PHB-71 showed 3.5 per cent enhancement in HI and a very little (about 6 per cent) reduction in economic yield, so it could be sown under high light intensity. PA-6129 with 19.9 per cent enhancement in grain yield and a little reduction in HI (10.2 per cent) may also be good for delayed sowing. Similar results were found by Abou Khalifa *et al.* (2005). The transplanting date had a significant effect on harvest index (Faghani *et al.,* 2011). Recently, Abou Khalifa *et al.* (2014) showed that early sowing resulted in highest harvest index, while late sown varieties gave the lowest value.

Total carbohydrate and amylose content

The quality of rice is mainly dependent on the composition of rice grains. It is reported that in general rice grains contain 90 per cent carbohydrate (starch), approximately 2 per cent lipids, 6–8 per cent proteins, and 1 per cent minerals of dry matter content of mild rice. The proportion of amylose and amylopectin is the key determinants that affect cooking quality of rice (Jang *et al.,* 2009). As the rice is photosensitive crop and variation in temperature especially during anthesis and flowering is a very important factor. It is not only the responsible for grain yield reduction but also deteriorate the grain quality. High temperature even after flowering decreases final viscosity and the amylose content to some extent. On the contrary, high temperatures can increase the maximum viscosity and breakdown values and hardness versus adhesion ratio of cooked rice (Tanaka *et al.,* 2006). All the quality parameters of rice can be affected by the growth conditions of plants, in particular, high temperatures during grain filling, field fertilization, and

In the present study, total carbohydrate and amylose content of grains of all late sown genotypes were decreased significantly when compared with normal sown genotypes (Fig. 1 a and b). The maximum total carbohydrate content (27 per cent) was observed in PHB-71 and NDR-359 in normal sown conditions which reduced more than half when sowing was delayed up to the fifteen days. KRH-2, PA-6129, AK-DHAN and VARADHAN showed 15- 50 per cent reduction in delayed sowing genotypes when compared with normal sown genotypes. This indicates that the total carbohydrate content on grains depends on light intensity during growth and reproductive stages in rice. The per centage of starch is significantly influenced by sowing time and genotypes. These results are corroborated with another study where a significant decrease of the total non-structural carbohydrates was observed in the grain, stem, and leaves as shading increased (Palis and Bustrillos, 1974). Starch content was higher in optimum sowing date compared to late sowing date and very late sowing date in different wheat genotypes (Hakim *et al.,* 2012). Various reports show that high temperature after flowering reduced the starch content and significantly influenced starch granule size distribution in wheat kernels (Zhao *et al.,* 2008).

Amylose content is directly related to volume expansion and water absorption during cooking and to the texture and cohesiveness of cooked rice. Delayed sowing with low light intensity reduced the amylose content by reducing the activity of starch synthesis enzymes. However, the increase in the activity of starch branching enzyme promoted amylose to change into amylopectin, which caused the decrease of amylose content. 4-18 per cent reduction in amylose content was observed in all the late sown genotypes. However, a very small reduction (4 per cent) was observed in late sown PA-6129 (fig. 1b). On the basis of better biological and grain yield this genotype might be suitable for late sowing or low light intensity.

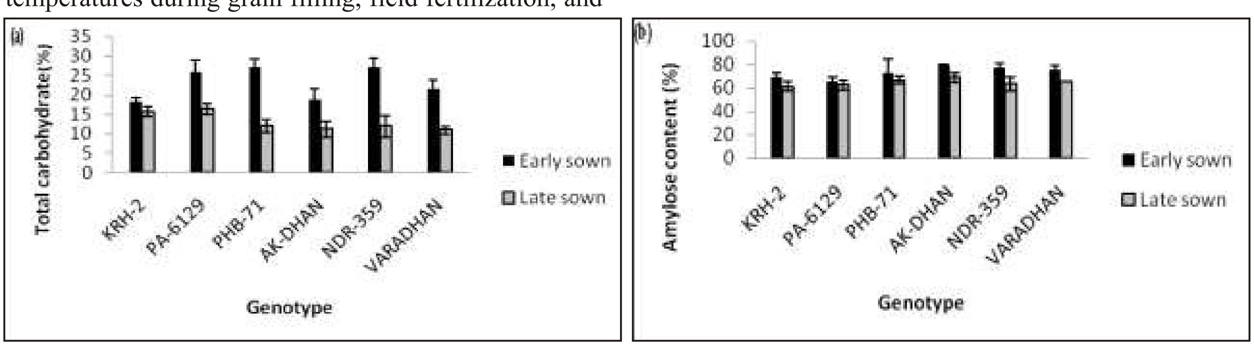

Fig. 1: (a) Total carbohydrate content and (b) amylose content (per cent) of different genotypes of rice under normal and late sown conditions. (Vertical bars indicate ± SE)

The decline of the sucrose content under shading is one of the important reasons for the decrease of starch synthesis. Various starch synthesis enzymes are also affected under the shaded treatments, which ultimately reduced starch content in grains (Tian *et al.,* 2006).

The ratio of amylose content to the total starch content displayed decreasing trend under shading, which is related to the changes in the activity of starch branching enzyme. In various early studies, it was concluded that the amylose content of crops was decreased under the weak light. This is because of the changes in starch synthesis reactions due to shading. This indicates that light intensity had obvious influence on the activities of starch synthesis and starch branching enzymes. The decline in the synthesis of sucrose is the major factor for reduced amylose/ starch content in the cereal crops (Tian *et al.,* 2006). It has also been determined that the effect of high temperature on amylose content is genotype-dependent (Cheng *et al.,* 2005). High temperature ripened rice grains contained decreased levels of amylose and long chain-enriched amylopectin, which might be attributed to the repressed expression of granule bound starch synthase (GBSS) as the amylose synthesis is exclusively governed by this enzyme however, amylopectin is synthesized via concerted reactions catalyzed by multiple isoforms of enzymes: soluble starch synthase (SS), starch branching enzyme (BE), and starch debranching enzyme. Decreased amount of amylose, amylopectin and chalky appearance are the characteristics of high temperature ripened grains of rice grown in field (Yamakawa *et al*., 2007).

CONCLUSION

The findings of the present investigation clearly indicate differential behavior of genotypes for photoperiod i.e., most of the rice hybrids were found sensitive to the photoperiod and performed better under normal sown condition as compared to inbreds under late sown condition. Among the hybrids, PA-6129 was comparatively less sensitive to photoperiod and performed better under late sown condition, while among the inbreds VARADHAN was comparatively less sensitive to photoperiod and maintained less reduction in yield under late sown condition. Better yield in normal sown condition may be due to the fact that in normal sown condition the crop gets more time for vegetative growth and a better light and temperature environment to establish itself as well as more capacity to translocate more photosynthate from vegetative part to grains than in late sown conditions. On the basis of better economic yield and very small reduction in amylose content, PA6129 could be recommended for late sowing or under low light intensity.

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