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An overview on the significance of sowing dates and nitrogen fertilization on growth and yield of rice

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Abstract
The impact of sowing dates and proper fertilization particularly nitrogen (N) on rice cultivation assumes pivotal significance. The dates of sowing and nitrogen fertilization have remained unequivocally the most important agronomic factors for obtaining optimum rice yields and will assume much higher importance under changing climatic conditions. Sowing time is a major factor in rice cultivation and indirectly determines soil temperature and weather conditions to which young seedlings and rice plants are exposed during different development stages. Moreover, an optimum sowing date in a particular ecological setting enables accumulation of desired growing degree days necessary for proper growth and development of rice crop. The optimum transplanting date is different in different agro-ecological settings. Under the temperate climatic conditions where crop growing season is generally short and sharp decline in temperature is noticed later in the season which is detrimental for crop growth, planting time assumes much greater importance. Similarly, optimum levels of nitrogen fertilization form an important aspect of overall fertilizer management in rice for its efficient utilization and higher productivity. Nitrogen fertilizer is a key input for rice production. Excess amount of N application can result in lodging of plant, greater susceptibility to pest infestation and reduction of yield. On the contrary, below optimum doses of N may affect different aspects of rice growth and will lead to stunted crop growth and lower yield, so judicious application of N is significant for obtaining optimum rice yields.

Keywords: Date of sowing, nitrogen, fertilization, growth, productivity, rice

Introduction

Rice, the world's single most important crop, is the primary food source for more than one third of the world's population (Hasamuzzaman *et al*. 2009; Wani *et al*., 2017) [1-2] and grown in 11 per cent of the world's cultivated area (Islam, 2009; Wani *et al*., 2017) [3, 2]. It is considered as the first cultivated crop of Asia and, owes prime importance to the food security of Asia where more than 90 per cent of global rice is produced and consumed. India is the largest rice growing country of world in terms of acreage and second in production (DES, 2012) [4]. The cultivation of rice is spread to varied latitudinal and altitudinal extents owing to its wide physiological adaptation. It is being grown successfully in tropics, subtropics and temperate regions up to 2000 m above mean sea level (Okon *et al*., 1998) [5]. It is endowed with amazing genetic diversity with more than one hundred thousand landraces and improved cultivars maintained in the germplasm collections spread world over. Because of its wide adaptation to different ecologies in addition to the horizontal and vertical expansion in the past, a pace has been maintained in the demand and supply chain. However, due to rampant population increase, yield plateauing and no further scope for horizontal expansion but rather dwindling land resources, rice crop is under tremendous pressure to keep pace with ever increasing demands. So, in order to maintain the rice production at desired levels a number of management options like adoption of new high yielding varieties, crop nutrition, weed management etc. can be modified to overcome the foreseen challenge. And, among the different components of agronomy packages for higher rice production which can be varied to meet the ever increasing production demands, date of sowing and nitrogen fertilization assume prime importance.

Sowing time is a major factor in rice cultivation and indirectly determines soil temperature and weather conditions to which young seedlings and rice plants are exposed during different development stages.

Planting time assumes much greater importance particularly under the temperate climatic conditions where crop growing season is generally short and sharp decline in temperature is noticed later in the season which is detrimental for crop growth. The optimum transplanting date is different in different agro-ecological conditions. Rice yield and quality are not only controlled by genetic factors, but are also largely influenced by environmental factors (Gao and Zhang, 1994) [6], such as light, temperature, soil type, soil water, cultivation measures, etc. (Hiroyuki *et al.*, 2002) [7], which can be manipulated to optimum level for higher crop yields through different management factors of which sowing date and nitrogen fertilization are of prime importance. Sowing and transplanting at the optimum time is important for obtaining higher paddy yields. The sowing date of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperature and high levels of solar radiation. Secondly, the optimum sowing date for each cultivar ensures that the cold sensitive stage occurs when the minimum night temperatures are historically the warmest. Thirdly, sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved (Farrell *et al.*, 2003; Wani *et al.*, 2017) [8, 2]. Too early or too late transplanting causes yield reduction due to crop sterility and lower number of productive tillers, respectively (Nazir, 1994) [9]. Rice being a thermophilic crop is sensitive to temperature extremes during specific developmental stages (Dingkuhn *et al.*, 1995) [10]. Temperature is the main driving force for development in photoperiod insensitive genotypes and heat unit accumulation and thus crop duration depends on the genotypic cardinal temperatures such as temperature sum, and base and optimum temperatures. Also yield in any given environment is the result of yield components developed in different development phases and growth stages. Yield potential is determined by the number of tillers formed during the vegetative growth phase, the number of panicles induced at the end of the vegetative stage, the number of spikelets formed in each panicle during panicle development, the number of fertile spikelets determined during the booting and flowering stage and the final individual grain weight determined during the grain filling phase (Dingkuhn and Kropff, 1996) [11]. All yield components are strongly influenced by the climatic conditions, the plant experiences during the respective phases the components are developed in. Planting date synchronises the optimum climatic conditions to the requirement of different phenological stages.

Likewise, optimum levels of nitrogen fertilization form an important aspect of overall nitrogen management in scented rice for its efficient utilization and higher productivity. Nitrogen fertilizer is a key input for rice production. Excess amount of N application can result in lodging and reduction in yield. On the other hand, deficiency of N may affect rice yield, so judicious application of N is important for obtaining better yield. Nitrogen is one of the most important nutritional elements for the higher productivity of cereal crops and a major factor that limits agricultural yields (Balasubramanian *et al.*, 2000; Islam *et al.*, 2009) [12, 3]. Nitrogen absorbed by rice during the vegetative growth stages contributes in growth during reproduction and grain-filling through translocation (Bufogle *et al.*, 1997; Norman *et al.*, 1992) [13-14]. Nitrogen is essential part of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Azarpour *et al.*, 2011) [15]. The application of nitrogen fertilizer either in excess or less than optimum rate affects both yield and quality of rice to remarkable extent, hence, proper management of crop nutrition is of immense importance (Manzoor *et al.*, 2006) [16]. Application of optimum levels of nitrogen is an important aspect of overall nitrogen management in rice for its efficient utilization, higher productivity and better quality. Excess application of nitrogen fertilizer can cause delay in crop maturity as well as high incidence of insect pest attack and lodging (Sidhu *et al.*, 2004) [17]. Keeping in view the large coverage and the role of rice in the agriculture economy an attempt has been made to review the pertinent literature regarding the impact of sowing dates and nitrogen levels on different aspects of rice under following headings:

Effect of sowing dates on
Growth characters

Chaudhary and Iqbal (1992) [18] reported that under normal planting, the mean plant height values for five seasons, from various locations of Pakistan were 159, 140 and 132 cm in cultivars Basmati-370, Basmati-198 and Basmati-385, respectively while as late planting was found to reduce plant height in all the cultivars. Paliwal *et al.* (1996) [19] reported that the mean plant height of basmati varieties reduced from 107 cm in June 25 to 83 cm in August 25 planting. Shivraj *et al.* (1991) [20] found no difference in dry matter accumulation under different dates of planting. Jand *et al.* (1994) [21] noticed reduction in dry matter accumulation with late planting (July 13) and the reduction was more in Basmati-370 compared to PR-109.The crop planted on June 13 and June 27 had similar dry matter accumulation. The leaf area index was also found to be higher in early planting. Vandana *et al.* (1994) [22] reported that dry matter accumulation in leaves decreased in test cultivars (PR-106, PR-109 and Basmati-370) with later transplanting dates. Wani *et al.* (2016) [23] reported significantly higher plant height (98.56 cm), tillers m^{-2} (333.41) and dry matter accumulation (9838 kg ha^{-1}) for early sown 15^{th} SMW (standard meteorological week) at par with 16^{th} SMW and significantly lowest growth parameters for 18^{th} SMW sown crop.

Crop Phenology

Chopra *et al.* (2006) [24] reported that days to 50 and 100 per cent flowering were significantly affected due to delay in transplanting. For occurrence of 50 and 100 per cent flowering, maximum number of days were required in June 30 transplanting and difference of 7-10 days was observed between June 30, July 28 and August 4 planting. Lee *et al.* (1994) [25] while working under southern Alpine conditions reported that the number of days from transplanting to maximum tillering decreased with delay in transplanting date. Peng-fei *et al.* (2013) [26] noticed that sowing date had significant effect on growth period. They reported a linear negative correlation between sowing date and growth period, in the later sowing dates. Bali *et al.* (1995) [27] reported that irrespective of cultivars, maturity of different cultivars occurs at the same date when transplanted in 1^{st} week of June. Results of field trials conducted in Wuling mountain area of China revealed that young panicle differentiation and heading dates were delayed at later sowing dates (Xie *et al.*, 1995) [28]. Song *et al.* (1996) [29] conducted studies in Korea and reported that delayed sowing decreased the number of days from sowing to heading in two rice cultivars. During dry seasons of west Bengal, the time to flowering decreased in successive sowings (3 dates from November to January) for IR-42, Jaya and IR-36 (Sinha and Chatterjee, 1997) [30].

The number of days between seedling emergence and 50 per cent heading declined linearly with delayed sowing dates (Gravois and Helius, 1998) [31]. Norman *et al.* (1999) [32] reported that the seedling date primarily influences the length of vegetative period of rice with early seeded rice requiring a greater number of days to accumulate the same number of degree days units compared with later seeded rice. Lalitha *et al.* (2000) [33] conducted field investigation in Hyderabad during *kharif* and *rabi* seasons and reported that during *kharif* season rice cultivars attained maximum tillering stage in 32-36 DAP, whereas during *rabi* season maximum tillering stage was attained in 46-55 DAP. Singh and Singh (2000) [34] from Uttaranchal reported that days taken to 75 per cent heading were not affected significantly by different sowing dates (15th March, 30th March and 15th April). Lee *et al.* (2001) [35] from Lorea reported that days from sowing to flowering were shortened as sowing dates were delayed from 25th April to 5th June in the field and phytotron experiment. The time taken for maturity ranged from 116.2 to 120.8 days for different sowing dates and 105-127.3 days for different cultivars (Mandal and Ghosh, 2003) [36]. A field experiment conducted in Maharashtra by Dixit *et al.* (2004) [37] showed that panicle initiation stage started late in early sown crop (5th and 10th June) and 50 per cent flowering was earlier in late crop (25th June). Experiments conducted at two locations viz. Crowley and St. Joseph in Louisiana showed that days from seedling emergence to 50 per cent panicle emergence decreased at both locations as planting was delayed (Linscombe *et al.*, 2004) [38]. Wani *et al.* (2016) [23] reported the days taken to reach flowering and harvest varied significantly among the sowing dates. The significantly higher number of days was taken by 15th SMW sown crop, however, was at par with 16th SMW crop while the significantly lowest number of days was taken by 18th SMW sown crop.

Temperature

High altitude systems (above 1600 msl) are constrained by temperature stresses and short vegetation periods (Shrestha *et al.*, 2011) [39]. Rice, a thermophilic crop is sensitive to temperature extremes during specific developmental stages (Dingkuhn *et al.*, 1995) [10]. Rice plants require a particular temperature for its phenological affairs such as panicle initiation, flowering, panicle exertion from flag leaf sheath and maturity and these are much influenced by the planting dates (Yoshida, 1981) [40]. Performance of rice is greatly influenced by the date of transplanting due to the effect of cold hazard and incidence of biotic stress (Halappa *et al.*, 1974) [41]. Deviation from the optimum planting time may cause incomplete and irregular panicle exertion, increased spikelet sterility (Magor, 1984) [42]. Late planting exposes the reproductive phases as well as phenological events of crop in an unfavourable temperature regime thereby causing high spikelet sterility and poor growth of the plant (BRRI, 1989) [43]. Temperature is the main driving force for development in photoperiod insensitive genotypes and heat unit accumulation and thus crop duration depends on the genotypic cardinal temperatures such as base and optimum temperatures and temperature sum (Dingkuhn and Kropff, 1996) [11]. Sowing date and location strongly influenced crop duration and grain yield of genotypes. Duration to flowering varied among planting dates for any specific genotype in low altitude between 5 and 31 with an average of 12 days, in mid altitude between 7 and 26 with an average of 16 days and in high altitude between 16 and 34 with an average of 24 days. Duration to flowering was longer than 100 days for all genotypes and planting dates in high altitude never shorter than 75 days in mid altitude and required a minimum of about 60 days in low altitude, thereby reflecting the thermal requirements of the genotypes (Shreshta *et al.*, 2012) [44]. According to Tanaka (1962) [45] flowering usually related to daily maximum air temperatures and the optimum daily maximum air temperature is 31-32℃. When the daily maximum air temperature is below 25℃, flowering is seriously curbed. A daily mean temperature exceeding 26℃ restricted the duration of tillering period to 5 weeks after planting and duration increased even up to 8 weeks after planting with temperature decreasing from 25.8 to 22.9℃ (Lalitha *et al.*, 2000) [33]. Bali *et al.* (1993) [46] reported that the crop transplanted beyond June 14 at an interval of 7 days up to July 5 was exposed to low temperature (12.5-25.6 ℃), at flowering stage (last week of August to first week of September), whereas the crop transplanted on June14 showed flowering by mid-August when temperature was better for pollination (17.1-29.3℃). Therefore, yield attributes like 1000-grain weight, panicles per square metre and number of grains per panicle was adversely affected by delayed transplanting resulting in poor yield in Kashmir Valley. Nahar *et al.* (2009) [47] reported that low temperature causes various types of injuries in rice plants, but the most important one is spikelet sterility. Moreover, filled grains production decreased significantly with the delay of transplanting which was due to occurrence of low temperature at anthesis and spikelet primordial formation. Oda and Honda (1963) [48] reported that the number of tillers increased with decreasing temperature. Matsushima *et al.* (1996) [49] noted that low temperature is not favourable for the elongation of tillers. Shimizu and Kumo (1967) [50] reported a wide range of abnormal spikelets, all of which were induced under the low temperature treatments at the young panicle primordium differentiation stage. Singh *et al.* (2005) [51] reported that yield losses due to low temperatures are the result of incomplete pollen formation and subsequent floret sterility. Bali *et al.* (1995) [27] reported that for late transplanting, low temperature at the pollen development stage may cause a sharp decline in fertile or filled spikelets particularly in the photo insensitive cultivars, which causes poor pollen germination and hence lower yields. Sthapit *et al.* (1997) [52] summarized from different authors that a temperature below 20℃ resulted in poor panicle exertion. Ahmad *et al.* (1996) [53] showed that delay in planting date cause improving sterile grain percentage significantly. Kumar (2002) [54] reported that under low temperature condition, a significant reduction in the rate of photosynthesis (36.8 %), canopy photosynthesis (44.14 %), transpiration (29.30 %), stomatal conductance (76.80) and level of photosynthetic pigments (52.51 %), nitrate reduction activity (51.61) was observed at grain filling stage. Besides, a reduction in the grain filling rate was also noticed under low temperature. Poussin *et al.* (2003) [55] found that cold temperature at the onset of the dry season induced slower development rate and lower above ground biomass despite higher plant and tiller density at panicle initiation. Slaton *et al.* (2003) [56] working under two geographical areas viz. Crowley and Stuttgart in USA reported that average daily high and low air temperatures for the predicted optimum sowing dates were 20 and 8℃ in Crowley and 24 and 11℃ in Stuttgart. The optimum time from emergence to heading was largely different between winter-spring season crop grown under low temperature condition (95-106 days) and rainy season(73-84days) crop grown under hot conditions (Kotera *et al.*, 2004) [57].

Growing Degree Days (GDD)

Chopra and Chopra (2004) [58] from Karnal (Haryana) studied the phenology and growing degree days (GDD) and its subsequent effect on seed yield and quality of Pusa Basmati-1. The crop transplanted on June 30 took 109.5 calendar days and 3125.9 growing degree days from transplanting to maturity (total phenophases) which got reduced almost linearly with delay in transplanting. Norman *et al*. (1999) [32] reported that although rice cultivars may have different cumulative degree day thresholds, the number of accumulated degree day units for development to specific growth stage (panicle differentiation and 50 per cent heading) remains relatively constant for a given cultivar. The thermal and photo thermal requirement of short duration (IR-8), medium (Sindewahi-75) and long duration (Jagarnath) rice cultivars transplanted at 15 days intervals from June 25 to August 20 at Nagpur, Maharashtra were measured by Ghadekar *et al.* (1988) [59] and noticed highest (1977) thermal units in early planting which decreased in late planting (1726). However, reverse was trend with photo thermal units. The results from field experiments in West Bengal revealed that the growing degree days during the periods between sowing and first leaf emergence including fourth leaf emergence and flowering increased with successive delay in sowing (Mandal and Ghosh, 2003) [36]. Reddy *et al.* (2004) [60] observed that the accumulated degree days for the vegetative growth of rice were 1074 and 1128 during *kharif* and *rabi* seasons, respectively. Brar *et al*. (2011) [61] reported that 10 to 20 days delay in transplanting led to 13 and 24 days reduction in total growing cycle of the crop under June 25 and July 5 transplanted crops as compared to June 15 transplanted crop, respectively. As a result, this led to reduction in accumulated growing degree days to the tune of 86 and 20 heat units to attain the maturity under June 25 and July 5 transplanted crop as compared to June 15 transplanted crop, respectively.

Yield Attributes

Yield in any given environment is the result of yield components developed in different development phases and growth stages. Yield potential is determined by the number of tillers formed during the vegetative growth phase, the number of panicles induced at the end of the vegetative stage, the number of spikelets formed in each panicle during panicle development, the number of fertile spikelets determined during the booting and flowering stage and the final individual grain weight determined during the grain filling phase (Dingkuhn and Kropff, 1996) [11]. Lin and Huang (1992) [62] from China reported that delay in transplanting beyond August 5 reduced grain filling percentage, 1000-grain weight and yield of rice. Singh *et al.* (1992) [63] from north-east plain zone Ghagra Ghat (India) reported that July 10 was an optimum time for transplanting of rice. Early or late planting crop reduced the yield attributing characters and yield significantly. The growth, yield attributes and grain yield recorded in July 5 planting were lower than July 20 planting. Uniform and well distributed rainfall received by July 20 planted crop favoured the yield. Singh (2003) [64] evinced that yield and yield related components of rice crop reduced with delay in transplanting. Singh and Pillai (1995) [65] from Hyderabad observed maximum panicles per square metre and panicle weight under July 16 planting than late planting on July 31 and August 16. Chopra *et al.* (2003) [66] at Karnal, studied the effect of different transplanting dates on seed yield of Pusa Basmati-1 and reported that transplanting on June 30 gave significantly higher panicle length (30.4 cm), panicle weight (3.83 g), 1000-grain weight (21.12 g) and seed yield (56.53 q/ha) than that of July 21, July 28 and August 4. Akbar *et al.* (2010) [67] studied the effect of six different dates *viz.* 31st May, 10th June, 20th June, 30th June, 10th July and 20th July for super basmati and concluded that 20th June produced maximum number of productive tillers per m^2, kernels per panicle, thousand kernel weight and paddy yield. Sahu *et al.* (1983) [68] found positive correlation of yield, number of grains per panicle and spikelet fertility with cumulative radiation during ripening stage. Tsai (1989) [69] found positive correlation of yield with number of spikelets per panicle and 1000-grain weight. Moreover, a positive correlation was observed between mean daily temperature and solar radiation with yield. Singh *et al.* (2004) [70] noticed significant reductions in yield attributes, yields and nutrient accumulation after delayed transplanting and concluded that timely transplanting on 3 July led to 8.4 and 19.1 per cent higher grain yield than transplanting on 10 and 17 July, respectively. Parihar *et al.* (1995) [71] observed no difference in 1000-grain weight of rice planted on June 30, July 15 and July 30. Mohapatra (1989) [72] noted significantly more biological yield under July planting compared to August planting and evinced that cultivars transplanted at higher temperature and less sunshine hours condition had more ripe grain and 1000-grain weight compared to lower temperature with more sunshine hours. Lower temperature coinciding with panicle initiation resulted in longer growing period and shorter plants. However, number of panicles and spikelets per square metre were found to be more in cultivars transplanted under lower temperature and higher sunshine hours.

Quality

Gill and Shahi (1987) [73] reported an increasing trend in head rice recovery with delay in planting from June 1 to July 30. The crop transplanted on July 30 gave 7.8-12.5 per cent more head rice yield than that transplanted on June 1, and 6.2-6.9 per cent more than that transplanted on June 30. Ali *et al.* (1991) [74] from Pakistan established the relationship between transplanting time and grain quality of basmati rice and reported that early and late transplanting dates depressed the milling recovery and cooking quality. The optimum transplanting dates were found to be July 1 and July 16 for Basmati-379 and Basmati-385, respectively. Bali and Uppal (1995) [75] from Ludhiana, reported that basmati rice transplanted on July 10 had 57 per cent head rice recovery but the recovery decreased to 54 per cent as a result of delay in planting to July 30. Rao *et al.* (1996) [76] studied the quality traits of Pusa Basmati-1, Haryana Basmati-1 and Basmati-370 under different dates of transplanting. It was reported that late planting on August 4 resulted in highest percentage of hulling (68.8 %) and head rice recovery (46%) compared to early planting. Also, the aroma in cooked rice did not differ significantly due to time of planting. Chandra *et al.* (1997) [77] reported that late planted rice (August 11) gave higher head rice recovery than early planted rice (July 25). Singh *et al.* (1997) [78] reported that Pusa Basmati-1 was superior to Kasturi in quality characters. Besides, better quality grains were produced from the crop transplanted late (July 20) than planted early (July 5). Chopra and Chopra (2004) [58] reported that transplanting up to middle of July was safe for higher seed quality. Chopra *et al.* (2006) [24] reported that all seed quality attributes were found to decrease with delay in transplanting from June 30 to August 4 with drastic reduction between July 28 and August 4 planting. Singh *et al.* (2005) [51] evaluated different scented rice cultivars for their yield potential under different fertilizer levels and transplanting dates. They reported that 25 July planting date recorded higher values of grain quality traits and yield compared to the 15 July planting date. Wani *et al*. (2016) [23] ascertained that head rice recovery showed a significant variation among sowing dates with highest head rice percentage for the 15th SMW (Standard meteorological week) sowing date (47.50) and lowest for the 18th SMW sowing date (39.50).

Yield

The production of Basmati rice can be increased with the manipulation of transplanting time and selection of genotypes having high yield potential (Singh and Singh, 2000) [34]. The early planted photoperiod sensitive rice varieties passed lag vegetative phase which increased tallness as well as biomass prone to lodging during grain filling stage. On the contrary, the late planted crop suffers due to low temperature during reproductive stage and sometimes panicle cannot emerge properly and some portions remain within the leaf sheath and, consequently, increases spikelet sterility and give low grain yield (Canet, 1986) [79]. Thus, by adjustment of transplanting time, the plant can take advantage of natural conditions favourable for its growth (BRRI, 2004) [80]. Nahar *et al.* (2009) [47] reported significant reductions in yield attributes and yields after delayed transplanting. Spikelet sterility was increased by late transplanting due to low temperature at panicle emergence stage. Yield reduction of BRRI dhan-46 due to late transplanting at 10 September, 20 September and 30 September were 4.44, 8.88 and 15.55 per cent, respectively compared to 1st September transplanting. In case of BRRI dhan-31 the reduction was more significant which were 6.12, 20.48 and 36.73 per cent, respectively. Trivedi and Kwatra (1983) [81] reported that June 30 planted crop produced highest (8 t ha^{-1}) grain yield which decreased linearly to the lowest level (3 t ha^{-1}) on August 15 planting. Urkurkar (1983) [82] studied that yield of pattern of dwarf Indica rice planted at 10 days interval from June 1 to august 30 and reported that transplanting between July 11 and July 21 was the optimum time for obtaining maximum grain yield at Raipur. Akram *et al.* (1985) [83] from Pakistan reported that Kashmiri Basmati planted on June 8 resulted in significantly higher yields than planted on May 24 and June 24. The varieties (Pusa Basmati-1, Jaya and PR-106) when transplanted 15 days later than recommended date experienced significant reduction in yield (Dhaliwal *et al.*, 1986) [84]. Narsingarao (1987) [85] studied the seasonal effect on 12 cultivars of rice at CRRI, Cuttack and reported that crop grown in dry season (January-May) gave 12 per cent higher yield than crop grown in wet season (June-November). Higher values of solar radiation and greater difference between maximum and minimum temperature during reproductive and ripening stage were ascribed for better yields in dry than wet season. Sinha and Biswas (1987) [86] from Cuttack reported that high yielding varieties of rice gave poor yield under August-September planting than July 9 planting. Om *et al*. (1993) [87] reported that gradual decrease in grain yield occurs with successive delay in transplanting from June 25 to August 4. Babu (1988) [88] reported highest grain yield under July planting and the reduction in grain yield was significant when planting was delayed beyond August 15. Higher yields under July 30 planting were attributed to the cumulative effect of more plant height, productive tillers and filled spikelets per unit area. Ashraf *et al.* (1989) [89] tested the performance of basmati-385 under different dates of transplanting (June 15, July 1, July 16, July 31and August 31) at NARC, Islamabad, Pakistan and reported that the grain yield decreased from 5.3 t ha^{-1} in July 1 planting to 2.7 t ha^{-1} in August 15 planting. The decline in yield under late planting was reported to be associated with less productive tillers and filled spikelets per unit area, as the crop was subjected to lower temperature regime under late planting. The reduction in grain yield of Gayatri was 22 and 50 per cent when the crop was planted in mid-August and mid-September, respectively compared with the normal planting (mid-July) at Cuttack. Transplanting of the crop in the early season resulted in better utilization of rain water than late in the season (Chandra and Mannan, 1989) [90].

Om *et al.* (1989) [91] tested the performance of Jaya (135 days) and HKR-120 (145 days) on three dates of transplanting at Kaul, Haryana and reported than grain yield of both the varieties decreased significantly with delay in planting. The reduction in grain yield due to late planting was 1.31 and 3.90 t ha^{-1} under July 5 and July 22 planting, respectively. In a field experiment at Ludhiana, Khushu and Mavi (1991) [92] tested the performance of PR-106, IR-8 (medium duration) and Palman-579 (short duration) which were transplanted on June 9, July 5 and July 31, respectively. It was found that grain yield in PR-106 and IR-8 was positively related to the energy received during flowering to maturity. In shorter duration cultivar, however, the highest grain yield was obtained from an intermediate light level under the July 5 transplanting compared to June 9 and July 31 transplanting. In the medium duration cultivar (PR-106 and IR-8), higher grain yield at high solar energy was due to more grains per panicle, grain weight per panicle and spikelet fertility. Reddy and Reddy (1992) [93] from Warangal, Andhra Pradesh, reported that rice cultivar Surekha planted on August 29 produced significantly higher yield than July 30 and August 14 planting. The increase in grain yield due to delayed planting was attributed to more productive tillers per unit area. Early transplanting dates received lesser solar radiation due to cloudy weather registering greater mortality of tillers and hence caused poor yield. Chaudhary *et al.* (1994) [94] reported that grain yield decreased significantly with delay in transplanting. Paul (1994) [95] reported from Assam that in Sali rice grain yield decreased from 3.1 t ha^{-1} on July 20 planting to 2.6 t ha^{-1} on September 2 planting. Munda *et al.* (1994) [96] obtained higher grain yield of rice cultivars (Khonorulla, PK-1 and PK-3) by transplanting on June 15 as compared to July 1. At Pantnagar, Pusa Basmati-1, Kasturi, Haryana Basmati-370 were studied at 5, 15 and 25 July transplanting during 1992 to 1994. It was found that July 5 planted crop gave significantly higher grain yield (3.5 t ha^{-1}) and thereafter a linear reduction was observed with every 10 days delay in planting. The grain yield reduction with delayed planting was of the order of 14 and 23 per cent under July 15 and July 25 transplanting, respectively compared to July 5 planting (Anonymous, 1995) [97]. Lakpale *et al.* (1995) [98] conducted a field experiment at Raipur to find out the suitable period of transplanting for photosensitive (Safari-17) and photoinsensitive (Kranti and Ananda) cultivars of rice. They noticed that both types of cultivars planted in July 3 produced significantly higher grain yield compared to early and late planting. Decreased effective tillers, panicle weight and fertility percentage were the cause for reduction in grain yield in early or delayed conditions. Katyal (1996) [99] observed 10.1, 4.1 and 57.1 per cent increase in grain yield in case of June 25 planting over June 15 and July 25, respectively.

Rao *et al.* (1996) [76] tested the performance of Basmati-370, Kasturi, Pusa Basmati-1 and Haryana Basmati-1 under 4 dates (July5, July 15, July 25 and August 4) of planting at Cuttack. The results revealed that July 15 to July 25 was the optimum time of transplanting for obtaining higher grain yield of basmati rice. Delayed planting beyond August 4 reduced the yield, which was attributable mainly to restricted tillering and crop growth and the incidence of insect pests. Lower grain yield under early (July 15) planting was ascribed to crop suffering due to heavy rains, water logging and cloudy weather during reproductive period in September. Mohammed *et al.* (2001) [100] reported that delayed planting (August 30) reduced grain production by 41 per cent compared to normal planting (July 15). Chopra and Chopra (2004) [58] advocated that late planting (July 28 and August 4) resulted in lower yield. Planting made up to middle of July was suitable for higher seed yield. Kumar and Ikramullah (2004) [101] reported that pre-released cultivar RNR-18833 was found significantly superior to popular variety Pusa Basmati-1 under normal planting (July 15) but had higher magnitude of reduction (43 %) in grain yield under delayed planting (August 30). Ram *et al.* (2005) [102] reported that highest grain yield (73.2 q/ha) was obtained with transplanting of rice on June 15, followed by transplanting on July 5 and July 25. The reduction in yield due to successive delay in planting was significant. Chopra *et al.* (2006) [24] reported that highest seed yield on July 21 (31.13 %), July 28 (42.48 %) and August 4 (70.50 %). Drastic reduction in all the yield parameters was observed at July 28 and August 4 planting. Manan *et al.* (2009) [103] in an experiment on fine rice genotypes, transplanted from 22 July to 7 October at an interval of 15 days reported that crop planted from 7 August to 7 September gave more number of tillers per m^2, panicles per m^2 and grains per panicle which resulted in higher grain yield. Compared to 22 August planting, grain yield decreased by 11, 10, 26, 43 and 61 percent, respectively, when crop was planted on 22 July, 7 August, 7 September, 22 September and 7 October. Hussain *et al.* (2009) [104] in an experiment used four planting dates *viz.* 25 of May, 2 June, 9 June and 16 June and reported that delay in planting beyond last week of May result in significant reduction of grain yield of basmati rice. The magnitude of reduction of grain yield observed with week delay in planting beyond 25 of May was 5.2, 9.9 and 12.3 q ha^{-1}. Earlier planting dates of 25 May and 2 June produced higher straw yield and higher harvest index than delayed planting of 9 and 16 June. Paliwal *et al.* (1996) [19] reported that transplanting on July 25 recorded significantly higher straw and grain yield compared to that on August 10 and August 15 planting. Iqbal *et al.* (2008) [105] reported 25.76 per cent higher yield in the early sown crop (1st week of July) than the late sown crop (3rd week of July) because of longer crop duration of the early sown crop. Bali and Uppal (1995) [75] from Ludhiana reported that earlier transplanting (July 10) of basmati rice increased the total dry matter production, grain and straw yield over late transplanting (July 30). Early transplanting developed better root density and favoured uptake of N, P, K and thereby increasing the grain yield.

Economics

Gangwar and Sharma (1998) [106] from Meerut, Uttar Pradesh worked out the economic analysis of different dates of planting of basmati rice and recorded higher mean net returns of Rs 12259 ha^{-1} and benefit cost ratio of 1.88 under July 1 planting followed by July 16 (Rs. 10028 ha^{-1} and 1.54), respectively. Further delay in planting reduced the net returns of Rs. 5211 ha^{-1} with benefit cost ratio of 0.80 under August 16 planting. Singh *et al.* (1999) [107] at Hyderabad recorded highest net returns of Rs. 13075 ha^{-1} along with maximum benefit cost ratio of 2.08 under December 30 planting followed by December 15 planting (Rs. 12125 ha^{-1} net return and benefit cost ratio of 1.93) and January 14 planting (Rs. 11825 ha^{-1} net return and benefit cost ratio of 1.88). Singh *et al.* (2000) [108] reported that timely transplanted (July 7) crop gave 18.7, 18.8 and 14.4 per cent higher return, benefit cost ratio and monetary production, respectively than late planted crop. Pusa Basmati-1 gave significantly higher grain yield (2930 kg ha^{-1}), net return (Rs. 24372 ha^{-1}) benefit cost ratio (4.54) and monetary productivity (Rs. 18053 ha^{-1} day^{-1}) than other varieties. Maximum net income of Rs 77282 was recorded when rice was sown on 20th June which was followed by the rice sown at 10th June and 31st May giving net income of Rs 62820 and 51109, respectively. The minimum net income of Rs 9907 was observed when rice was sown on 10th July. Thus the net benefit gradually decreased as sowing was done after 20th June and later on (Akbar *et al.*, 2010) [67]. Wani *et al.* (2016) [23] recorded highest B:C ratio (3.03) with sowing date of 15th SMW followed by 16th SMW and lowest with 18th SMW.

Effect of nitrogen fertilization on
Growth characters

Zhilin *et al.* (1997) [109] stated that plant height increased significantly due to nitrogen application. Haefele *et al.* (2008) [110] reported that N treatments had significant effect on plant height. The increased N levels increases plant height which may be caused by enhanced vegetative growth resulting from increase in cell size and meristematic activity. Moorthy *et al.* (1988) [111] reported a significant increase in the plant height with application of nitrogen up to 90 kg ha^{-1}. Tripathi *et al.* (1998) [112] showed significant increase in basmati plant height and dry matter production with successive increment of N up to 90 kg ha^{-1}. Chopra and Chopra (2000) [113] reported a significant increase in plant height and straw yields with increase in N levels in aromatic rice variety Pusa Basmati-1. Raju *et al.* (2001) [114] reported a significant increase in seedling height of rice at 100 kg N ha^{-1} over control, with increases in N levels, there was a significant increase in height of plants. Application of 150 per cent of recommended dose of N (75 kg ha^{-1}) gave significantly greater dry matter production. The beneficial effect of nitrogen on tillering and vegetative growth was reported by Reddy (1988) [115], moreover, there was more accumulation of dry matter at all the stages of sampling with increase in nitrogen levels from 0 to 120 kg N ha^{-1} and gave higher values of crop growth rate over 40 to 80 kg N ha^{-1}.

Sharma and Singh (1999) [116] observed that application of nitrogen had a significant effect on dry matter accumulation. They reported that the difference between 0 and 60 and 60 and 120 kg N ha^{-1} being significant at most of the observations. Panda and Rao (1991) [117] found increased dry matter production with subsequent increase in nitrogen application up to 120 kg N ha^{-1}. Dry matter production increased significantly with the increasing level of N up to 90 kg N ha^{-1} (Khanda *et al.* 1997) [118]. Aromatic rice showed significant increase in dry matter production with each successive increment of N from 0 to 180 kg ha^{-1} (Gangaiah and Prasad, 1999) [119]. Leaf area index (LAI) is a determining factor of photosynthetic production of the crop and an important character to evaluate the characteristics of dry matter production (Kusuda, 1993) [120]. Amano *et al.* (1993)

[121] reported that irrespective of cultivars and nitrogen levels, LAI increased sharply after transplanting attaining a peak at heading stage and then decreased gradually. Maske *et al.* (1997) [122] reported that increasing nitrogen levels up to 120 kg N ha^{-1} significantly increased leaf area, yield component and grain yield. Verma *et al.* (2004) [123] recorded that the N content in the third leaf, chlorophyll a content increased with increasing nitrogen application rate. Application of nitrogen directly increased the chlorophyll content and leaf surface area resulting in increased photosynthesis process leading to more sugar formation (Dikshit and Paliwal, 1989) [124]. The number of panicles, panicle length and percentage of spikelet sterility increased with the increase in nitrogen levels (Manan *et al.*, 2010) [125]. Chakraborty (2011) [126] reported a significant increase in the number of leaves per hill up to 100 kg N application, while the further increase in the number of leaves per hill with the increase in the nitrogen dose was found insignificant. Tari *et al.* (2009) [127] reported that nitrogen fertilization levels had significant effect on flag leaf area, flag leaf angle, panicle length and grain yield. Wani *et al.* (2016) [23] reported significantly highest plant height (98.12 cm), tillers m^{-2}(343.33) and dry matter accumulation (1006 kg ha^{-1}) for N_{80} level, at par with N_{60} level, and significantly lowest growth parameters for N_{40} and control.

Phenology

Mahajan *et al.* (2010) [128] reported that the high level of N fertilizer (60 kg N ha^{-1}) delayed flowering by 2-3 days in 'Pusa 1121' and 'Punjab Basmati 2', while in unfertilized plots, flowering was early by 2 days, irrespective of the cultivar used. Delayed flowering with higher N dose may be due to more vegetative growth. Abou-khalifa *et al.* (2007) [129] found that maximum tillering, panicle initiation, heading date, crop growth rates, leaf area index, and grain yield were increase by increased nitrogen levels of up to 165 kg N ha^{-1}. Haque *et al.* (2006) [130] conducted an experiment to study the effect of nitrogen fertilizer on yielding ability of indigenous aromatic rice cultivars namely, Shakkorkhora, Chinigura, Kalijira and Kataribhog, each with three levels of nitrogen fertilizer (0, 60 and 120 kg N ha^{-1}) and reported that irrespective of cultivars, the days required to flowering and maturity significantly increased with the increase in the amount of nitrogen applied. Crop maturity was delayed by almost 9, 6, 13 and 7 days at 60 kg N ha^{-1} and by 17, 14, 11 and 12 days at 120 kg N ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. Accelerated vegetative growth might be a factor for delaying flowering and crop maturity with the increase in the amount of nitrogen fertilizer. Wani *et al*. (2016) [23] reported that among the nitrogen levels 80 and 60 kg N ha^{-1} took significantly more number of days to reach flowering and harvest than 40 kg N ha^{-1} and control. The delayed flowering with higher nitrogen dose may be due to more vegetative growth, as reflected by increased plant height, which delayed maturity.

Yield Attributes

Gangaiah and Prasad (1999) [119] observed increase in growth, yield attributes, grain and straw yield, NPK and zinc uptake within each successive increment of nitrogen use from 0 to 180 kg ha^{-1}. Chopra and Chopra (2000) [113] reported linear increase in yield with nitrogen application up to 80 kg ha^{-1} and thereafter marginal reduction in yield was recorded at 120 kg ha^{-1}. However, straw yield increased up to the highest levels of N. The optimum economic dose for nitrogen was worked out to be 98.5 kg N ha^{-1}. Manzoor *et al.* (2006) [16] reported that plant height, number of productive tillers per hill, panicle length, number of grains per panicle, 1000 grain weight and paddy yield showed increased trend from 0 to 175 kg ha^{-1}. Maximum paddy yield was obtained from 175 kg ha^{-1} N application treatment which also produced highest values of number of grains per panicle along with maximum 1000 grain weight. Kanyika *et al.* (2007) [131] in an experiment on Nunkile (Pusa 33), an aromatic rice variety, reported that the number of panicles, filled grains per panicle, panicle length and panicle weight increased with increased levels of nitrogen fertilizer. Kumar and Ikrammullah (2004) [101] conducted an experiment with 4 nitrogen levels (0, 50, 100 and 150 kg ha^{-1}) and 2 planting dates (15 July and 30 August) to determine the nitrogen requirement of scented rice cultivars under normal and late planting. They reported that productive tillers m^{-2}, filled grains per panicle, panicle weight, grain yield, net returns and benefit:cost (BC) ratio, increased with increasing nitrogen rate and decreased with delay in planting. Manan *et al.* (2010) [125] reported that the plant height, tiller number, number of panicles, panicle length and straw yield increased with increased nitrogen levels up to 75 kg ha^{-1}. Maximum plant growth at the highest level of nitrogen (100 kg ha^{-1}) caused lodging of plant which increased spikelet sterility and ultimately decreased grain yield. Sharma *et al.* (2012) [132] reported that the yield contributing characters, panicles per m^{-2}, grains per panicle, yield and B:C ratio was high with nitrogen and phosphorous 90 and 45 kg ha^{-1}, respectively. Application of N_{90} P_{45} kg ha^{-1} also showed highest N and P uptake. Haque *et al.* (2006) [130] reported that tillers per hill increased over time showing a peak at around maximum tillering stage and thereafter declined. The tiller number increased with increase in nitrogen levels from 0 to 120 kg N ha^{-1}. Maximum tiller number was noticed at nitrogen level of 120 kg N ha^{-1}, which was statistically similar at 60 kg N ha^{-1}. They also reported that, after maximum tillering stage tillers per hill decreased considerably until maturity. This suggests that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate. A high tiller mortality rate was also observed by Roy and Sattar (1992) [133] during the later stage of plant growth.

Individual grain weight is usually a stable varietal character and the management practice has less effect on its variation (Yoshida, 1981) [40]. Shivay and Singh (2003) [134] observed no significant difference in 1000-grain weight due to the application of nitrogen. Haque *et al.* (2006) [130] reported no significant difference in 1000-grain weight among the cultivars with different N levels. Chakraborty (2011) [126] in an experiment with seven doses of inorganic N fertilizer *viz* 20, 40, 60, 80, 100, 120, 140 kg ha^{-1}, reported that yield attributing characters differed considerably among the treatments. Maximum panicle length (1.71cm), effective tiller number/hill (62.01), filled grain number/panicle (66.12), tiller number/hill (11.27), leaf number/hill (48.11) and leaf width (9.11 mm) was noted when the field was fertilized with 100 kg N ha^{-1}. But no significant improvement of yield attributing characters except the number of filled grain number/panicle was noted when the dose of fertilizer was increased after 100 kg N ha^{-1}. Singh *et al.* (2004) [70] reported that increased nitrogen levels had a significant effect on yield attributes (except 1000-grain weight), yields and nutrient accumulation up to 120 kg N ha ha^{-1}. Also the maximum grain yield (5.87 t ha ha^{-1}) was recorded at the highest level of N nutrition (180 kg N ha^{-1}) and was 4.2, 15.5 and 39.3 per cent higher than in the 120 kg, 60 kg N ha^{-1} and control treatments, respectively. Islam *et al.* (2008) [135] in an experiment on the effect of nitrogen levels and transplanting dates on the yield of aromatic rice cv. Kalizira reported that most of the yield and yield contributing characters were significantly influenced by nitrogen levels and transplanting dates. They had significant positive effect on tillers per hill, grains per panicle and straw yield. The highest grain yield was observed on 10th August with nitrogen rate of 100 kg ha^{-1}. Also, highest grain length, grain breadth and imbibition ratio were also observed on the same date and nitrogen level while the lowest yield was obtained for crop planted on 4th September with no nitrogen applied.

Quality

Devi *et al.* (2012) [136] reported that the yield attributes of scented rice under aerobic culture responded up to 150 kg ha^{-1} nitrogen with 4 equal splits of N at ¼ basal+1/4 at active tillering + ¼ panicle initiation and ¼ at heading. Grain quality parameters like milling percentage, head rice recovery, kernel length, breadth, amylose content and protein content of rice registered significantly highest values with 150 kg ha^{-1} nitrogen. Perez *et al.* (1996) [137] reported appreciable increase in protein content with the application of nitrogen which was mainly due to higher nitrogen concentration. They also reported that high protein content improves milling and head rice recovery percentage High-protein rice is more resistant to abrasive milling than low-protein rice (Cagampang *et al.*, 1966) [138]. Singh *et al.* (1997) [78] concluded that protein content, kernel length, breadth and percent recovery of head rice significantly increased with increasing levels of nitrogen. Khalid and Chaudhry (1999) [139] reported that among the different nitrogen levels (0, 40, 80 and 120) used, treatment where N was used at the rate of 80 kg ha^{-1} gave significantly higher percentage of seed protein and amylose content than rest of treatments. Conry (1995) [140] reported that increased rate of N fertilizer could increase yield but reduced the quality of grains. Sharma and Singh (1999) [116] reported that excess nitrogen application reduces carbohydrate content resulting in abnormal development of pollen grains. Wani *et al*. (2016) [23] reported that different levels of nitrogen showed significant difference in head rice recovery and higher head rice per cent was recorded for crop receiving 80 kg N ha^{-1}(44.54) and lowest for control (41.84).

Grain and straw yield

Akita (1989) [141] reported that crop environmental conditions with high solar radiation during the growing season and abundant supply of N favoured accumulation of high amount of biomass and high yields provided varieties respond favourably to nitrogen. Fageria (2003) [142] and Shinano *et al*. (1995) [143] reported that in cereals including rice, N accumulation is associated with dry matter production and yield of shoot and grain. Khalid *et al.* (1999) [144] reported that the application of nitrogen at the rate of 80 kg ha^{-1} appeared optimum to get higher yield followed by nitrogen level of 120 and 40 kg ha^{-1} in descending order. Ehsanullah *et al.* (2001) [145] tested three nitrogen levels (75, 100 and 125 kg ha^{-1}) and reported minimum yield of 4.29 t ha^{-1} at the nitrogen level 75 kg N ha^{-1} and maximum yield of 4.72 t ha^{-1} at 125 kg N ha^{-1}. Pramanik and Bera (2013) [146] tested five levels of nitrogen viz. N0, N50, N100, N150 and N200 kg ha^{-1} and reported that among the nitrogen levels N200 kg ha^{-1} gave significant higher plant height, panicle initiation, number of tillers hill^{-1}, total chlorophyll content, panicle length and straw yield and nitrogen levels N150 kg ha^{-1} gave significant higher number of effective tillers^{-1}, effective tiller index, panicle weight, filled grain panicle^{-1}, 1000 grain weight, grain yield, and harvest index as compared to N0, N50, N100 during both years. N150kg ha^{-1} produced significantly highest grain yield of 6286 and 6652 kg ha^{-1} in 2010 and 2011, respectively. The grain yield increased by 72.5, 44.4, 23.8 and 5.1 per cent in first year and 69.9, 44.1, 22.1 and 3.5 per cent in second year over N0, N50, N100 and N200 kg ha^{-1}, respectively. Manan *et al.* (2010) [125] reported that straw yield increased significantly with the nitrogen rates up to 75 kg N ha^{-1} and no significant difference in straw yield was found between 75 and 100 kg N ha^{-1}, but 100 kg N ha^{-1} showed higher straw yield than other levels of N. This suggested that vigorous crop growth with the nitrogen treatments might have resulted in higher straw yields of fine rice. Furthermore, the optimum level of nitrogen for the cultivation of Basmati fine rice was about 69-70 kg N ha^{-1}. Rao *et al.* (2013) [147] reported that at all growth stages dry matter production, grain yield, straw yield, harvest index and nitrogen uptake were maximum at 240 kg ha^{-1} which was significantly superior over low level (120 kg N ha^{-1}). N uptake increased with increase in the levels of nitrogen up to 240 kg ha^{-1}. N uptake at 240 kg N ha^{-1} was significantly higher at all growth stages, grain, straw and total uptake which was comparable with 210 kg N ha^{-1}. The minimum (13.4 kg ha^{-1}) N uptake was recorded with 120 kg N ha^{-1}. This increase in growth might be due to enhanced cell division and cell elongation induced by abundant nitrogen supply with increase in nitrogen levels, favouring enlargement and better development of panicle resulting in more number of total grains per panicle and keep leaves green even at the time of maturity. Hence, the contribution of carbohydrates from photosynthetic activity resulting in efficient translocation of food material into the sink (grain) thereby increased number of filled grains per panicle.

Mahajan *et al.* (2010) [128] reported that aromatic cultivars of rice respond differently to nitrogen application as compared to non-aromatic rice. They conducted an experiment to optimize N levels for higher yield and nutrient use efficiency (NUE) of modern aromatic rice cultivars and reported that across all genotypes, the mean nitrogen-fertilizer response was highest at 40 kg N ha^{-1} as compared to other N levels (0, 20, and 60 kg N ha^{-1}), indicating that further increase in N level had no effect on crop response to fertilizer. The mean grain yield increased by 64.2 per cent when plots were supplemented with 40 kg N ha^{-1} as compared to control (unfertilized). Pal *et al.* (2001) [148] studied the effect of transplanting time (28 July and 8 August) and N level (0, 30, 60 and 90 kg ha^{-1}) on the production potential and profitability of scented rice and evinced that transplanting time did not influence the grain yield while the increasing N levels up to 60 kg ha^{-1} increased the grain yield and net return. Gautam *et al.* (2008) [149] ascertained that application of 160 kg N ha^{-1} recorded 23.7 and 26.1 per cent more grain yield over no nitrogen application whereas it was 6.4 and 6.1 per cent more over 80 kg N ha^{-1}, respectively, during first and second year of the experimentation. Sreenivas and Reddy (2008) [150] reported increase in biomass with increasing levels of nitrogen from 100 to 300 kg ha^{-1}. Dalal and Dixit (1987) [151] reported that higher levels of N application cause better N uptake, leading to greater dry matter production and its translocation to sink. Jadhav *et al.* (2004) [152] noticed significant increase in grain and straw yield of Basmati rice with higher levels of nitrogen at 120 kg ha^{-1} under upland condition. Luikham *et al.* (2008) [153] reported highest grain yield, net income and cost benefit ratio with the application of nitrogen at 60 kg^{-1} ha. Singh *et al.* (2005) [51] observed that application of graded levels of N up to 90 kg N ha^{-1} increased grain yield linearly. Akram *et al.* (1985) [83] studied the effect of planting dates and fertilizer levels on grain yield and protein content of Kashmir Basmati and noted considerable variability in grain yield and protein content with different combinations of transplanting dates and fertilizer levels. The maximum grain yield (4.48 t ha^{-1}) was recorded when crop was transplanted on June 8 with fertilizer level of $N_{90}P_{45}$. Pramanik and Bera (2013) [146] observed significant effect of nitrogen levels on harvest index of hybrid rice. Among different nitrogen levels used (N0, N50, N100, N150 and N200 kg ha^{-1}), they reported that the nitrogen level of N150 kg ha^{-1} registered the highest harvest index (46.40 and 47.07) as compared to other nitrogen levels, respectively during the both years. The minimum harvest index (42.48 and 42.6) was observed in the control plot.

Nutrient Uptake

Nitrogen taken up during early growth stages accumulates in the vegetative parts of the plant and is utilized for grain formation. A large portion of the nitrogen is absorbed during differentiation. The leaves and stem contain a large portion of the nitrogen taken up by the plant (Milkkelson, 1982) [154]. Nitrogen fertilization has a vital role in determining the percentage nitrogen in the rice grains and nitrogen uptake by the rice plants (Ebaid and Ghanem, 2001) [155]. The recovery of N fertilizer applied to the rice crop would range from 30 to 40 per cent. However, with improved cultural practices, such recovery can increase up to 65 per cent (De Datta, 1981) [156]. The growth duration, native soil fertility and cultural practices affect N absorption pattern, which in turn affects the amount of N in plants leading to profound effect on N use efficiency (Cruz and Wada, 1994) [157]. Nitrogen use efficiency has been defined in various ways, like total N uptake, physiological nitrogen use efficiency (PNUE), apparent nitrogen recovery efficiency (ANRE) and agronomic nitrogen use efficiency (ANUE). These definitions generally take into account quantity of N accumulated in the plant, known as uptake efficiency and quantity of N utilized in grain production known as utilization efficiency. Fageria (2003) [142] and Shinano *et al*. (1995) [143] reported that in cereals including rice, N accumulation is associated with dry matter production and yield of shoot and grain. Rice varieties responded differently to N application and differed in their ability to extract soil and fertilizer N (Swain *et al.*, 2006) [158]. According to Wada and Cruz (1994) [159], the low absorption ability at the early growth stage is compensated by higher basal N application and narrow spacing in short-duration varieties. Information on the seasonal N uptake patterns and partitioning within the crop is valuable in assessing the amount of, timing and method of N fertilization to prevent the occurrence of N deficiencies or over fertilization (Islam *et al.*, 1996; Saito, 1991) [160-161].

Quanbao *et al.* (2007) [162] showed that ANRE increased with increasing N application in sandy soil while it increased firstly and reach to the maximum under 225 kg ha^{-1} N application, then declined significantly under 300 kg ha^{-1} N application in clay soil indicating that it was not useful for improvement of ANRE with more or less N application. Physiological N use efficiency (PNUE) of all varieties decreased with increasing N application. It showed that yield increased per kilogram N accumulated in rice plant was decreased with increasing N application (Tayefe *et al.*, 2011) [163]. Quanbao *et al.* (2007) [162] showed that under two soil conditions, PNUE of all genotypes decreased significantly with increasing N application, it was higher in sandy soil than that in clay soil. Tayefe *et al.* (2011) [163] reported that agronomic nitrogen use efficiency (ANUE) decreased with increasing N application. It indicated that the capability of yield increase per kilogram pure N declined remarkably with increasing N application.

Pillai and Rajat (1980) [164] studied the nutrient uptake in rice variety *Jaya* as influenced by graded levels of N and time of N application and reported the grain nitrogen content was highest, when nitrogen was applied in two split doses at planting and panicle initiation. The apparent recovery of N was maximum (54 %) at 100 kg N ha^{-1}, beyond which there was a decline in percentage recovery of applied nitrogen. Split application of N and continuous shallow submergence resulted in higher recovery of added nitrogen leading to better uptake of P and K, as well. Prudente *et al.* (2008) [165] conducted an experiment to determine the effect of different levels of N on N uptake, yield components and dry matter yield of *japonica* (*Hatsuboshi*) and *indica* (*IR-13*) rice varieties. They reported an increasing trend in the N uptake, rice yield, panicle number, tiller number and dry matter production with increased amount of applied N fertilizer. The yield (brown rice) of the two varieties (*Hatsuboshi*, 3.2-6.5 tons ha^{-1}; *IR-13*, 2.6-6.4 tons ha^{-1}) did not differ significantly ($p=0.05$). However, the agronomic efficiency (AEN) of *IR-13* was significantly higher than *Hatsuboshi*. There was a 30 kg ha^{-1} increase in the yield of brown rice and about 1.4 per cent increase in the total N uptake for every additional kilogram of applied N ha^{-1}. Higher correlations ($p=0.001$) were found between the yield (r = 0.96; r = 0.99), number of panicles (r = 0.98; r = 0.96) and number of tillers (r = 0.96; r = 0.97) and N uptake (r = 0.97; r = 0.95) of *japonica* and *indica* rice varieties and applied N, respectively. The increase in yield (ton ha^{-1}) of *japonica* ($y = 1.07x + 2.5$) and *indica* ($y = 1.24x + 1.5$) could be attributed to the increase in N uptake with increased application of N and mineralized soil N after flooding.

Tayefe *et al.* (2011) [163] conducted an experiment using three rice cultivars (Hashemi, Kazemi and Khazar) and four nitrogen levels [(N1-control (no N fertilizer); N2- 30 kg ha^{-1} N (at transplanting time); N3- 60 kg ha^{-1} N (at transplanting, and tillering times); N4- 90 kg ha^{-1} N)] to study the effects of nitrogen fertilizer on nitrogen use efficiency, yield and characteristics of nitrogen uptake. They reported that total N uptake, physiological nitrogen use efficiency (PNUE), apparent nitrogen recovery efficiency (ANRE) and agronomic nitrogen use efficiency (ANUE) varied in different cultivars significantly and Khazar variety had the highest contents. Total N uptake, physiological N use efficiency (PNUE), agronomic nitrogen use efficiency (ANUE) varied significantly with the increment of the amount of nitrogen applied. As total N uptake increased with increase in N fertilizing contents but physiological N use efficiency (PNUE), agronomic nitrogen use efficiency (ANUE) decreased. There were significant differences in the effects of applying nitrogen fertilizer on nitrogen use efficiency and characteristics of nitrogen uptake. Sharma and Singh (1999) [116] reported positive effect of N uptake on grain yield due to increase in sink size, because spikelet degeneration decreases linearly with increasing N concentration in the leaf at anthesis.

SPAD Reading

Nitrogen is essential part of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Azarpour *et al.*, 2011) [15].

Chlorophyll pigments play an important role in the photosynthetic process as well as biomass production. Genotypes maintaining higher leaf chlorophyll-a and chlorophyll-b during growth period may be considered potential donor for the ability of producing higher biomass and photosynthetic capacity. Higher photosynthesis rate is supported by leaf chlorophyll content in leaf blades (Hassan *et al*., 2009) [166]. Rate and timing of N is critical for optimum rice grain yield (Doberman and Fairhurst, 2000) [167]. Judicious use of nitrogen (N) fertilizer in rice requires synchronizing N fertilizer application with plant needs. Deep placement of urea, split N application and the chlorophyll meter and leaf colour chart techniques are some N management strategies that could improve fertilizer use efficiency in rice (Kumar *et al*., 2000) [168]. Innovative tools such as the chlorophyll or SPAD meter offer a new strategy for optimizing fertilizer nitrogen(N) application in rice, indicated that critical spad values could be established for different varieties and growing season, depending on local growing condition (Babu *et al*., 2000) [169]. The chlorophyll meter which measures leaf greenness can predict the need for N top-dressing at panicle initiation and panicle differentiation for rice, meter reading are given in Minolta company-defined SPAD (Soil Plant Analysis Development) values that indicate relative chlorophyll contents (Turner, 2002) [170]. The chlorophyll meter indicates the need of a nitrogen top dressing that would result greater agronomic efficiency of nitrogen fertilizer than commonly pre-application of nitrogen (Hassan *et al.,* 2009) [166]. The chlorophyll or spad meter offers a new strategy for synchronizing N application with actual crop demand in rice. The chlorophyll meter can be used to monitor plant N status in the field and to determine the right time of N top-dressing in rice (Balasubramanian *et al.*, 2000) [12]. Chlorophyll meter provides instantaneous on-site information on crop N status as spad reading in a non-destructive manner (Swain and Jagtap, 2010) [173].

The chlorophyll meter quantifies the greenness or relative chlorophyll content of leaves (Hassan *et al.*, 2009) [166]. Several factors affect spad values such as radiation differences between seasons, plant density, varietal groups, nutrient status other than N in soil and abiotic stresses that induce leaf discoloration (Balasubramanian *et al.*, 2000) [12]. Gholizadeh *et al.* (2011) [172] reported that analyses of collected data at different growth stages were useful to determine when SPAD data can be used to predict leaves total N amount and future crop N need, the increasing of SPAD reading values with growth stages was noticed. Apply only a moderate amount of fertilizer N to young rice within 14 day after transplanting (DAT) or 21 (DAS) days after sowing, when the growth and need of the plant for supplemental N is small, reduce or eliminate early application of fertilizer N when high-quality organic materials and composts are applied or the soil N-supplying capacity is high (Buresh *et al.,* 2006) [173]. Hassan *et al.* (2009) [166] showed that the SPAD reading indicated the plant nitrogen status and the amount of nitrogen to be applied are determined by the physiological nitrogen requirement of crop at different growth stage. Chen *et al.* (1997) [174] reported that the chlorophyll level in the normal leaves decreased progressively with age. Balasubramanian *et al.* (2000) [12] showed that differential rates of N application can be worked out based on observed SPAD values at critical stages of growth (early tillering, active tillering, panicle initiation, and first (10 %) flowering). If these observations are confirmed, the number of SPAD measurement and split N applications will be reduced. Islam *et al.* (2009) [3] reported that strong relationship between SPAD values and leaf N concentration but this relationship varies with crop growth stage and or variety, mostly because of leaf thickness or specific leaf weight. However the relationship between leaf N content and SPAD value indicated that when a variety will show higher SPAD value, it has certainly higher amount of nitrogen. Kumar *et al.* (2000) [168] showed that the highest SPAD values were observed at the maximum tillering stage for all varieties. Youseftabar *et al.* (2012) [175] studied the effect of split application of nitrogen fertilizer on spad values in hybrid rice (GRH1). Four nitrogen levels (100,200 and 300 kg ha^{-1}) were applied in the form of split application at three levels [(T1= (1/2basal-1/2mid tillering), T2 = (1/3basal-1/3mid-tillering-1/3panicle initiation) and T3= (1/4basal-1/4 mid tillering-1/4panicle initation-1/4 flowering)]. They reported that SPAD values increased significantly with nitrogen fertilizer. The interaction effect of treatments revealed that all the SPAD values increased significantly with an application of 300 kg ha^{-1} N-fertilizer at 4 stage. Timing of nitrogen application can apply four or three times at different growth stage based on crop need and SPAD threshold and crop-growing condition at each location. The results revealed that N application method based on growth diagnosis helped in saving N applied fertilizer and increasing grain yield. Peng *et al.* (1996) [176] reported that yields with SPAD-based management were 93-100 per cent of maximum yields achieved by the best fixed-timing treatment with the lower total N rates used in all SPAD-based N treatments. Increased recovery efficiency from applied N and greater utilization of the acquired N to produce grain contributed to the significantly greater fertilizer-N efficiency of the SPAD-based than of the fixed-timing N treatments. The improved congruence of N supply and crop demand in SPAD-based treatments resulted in fewer unproductive tillers, less leaf senescence at flowering stage and comparable or greater crop growth rates after flowering than the best fixed-timing treatment.

Conclusion
The perusal of the literature suggests that sowing time and nitrogen fertilization rate are the two most pivotal agro-inputs which describe the rice yield to a major extent. However, the optimum date of planting and nitrogen rate vary in the different agro-ecological settings owing to varying relief, topography and weather determinants. There is a consensus in the literature that the synchronisation of the critical phenophases with the favourable weather regime ensures promising crop yield which is only possible by adjusting the sowing date. Nitrogen application can increase both quantative and qualitative traits of rice when applied properly. Both sowing date and nitrogen fertilization has positive impact on the economy of rice. Therefore, it is imperative to confirm best sowing date and nitrogen level for rice agronomy under different agroclimatic zones of the world for higher yield levels and food security.

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