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Response of dry seeding of *kharif* paddy (*Oryza sativa* L.) Varieties to different fertilizer levels with respect growth characters

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Abstract
The agronomic investigation entitled, "Response of dry seeding of *kharif* paddy (*Oryza sativa* L.) varieties to different fertilizer Levels" was undertaken at Post Graduate Research Farm, Agronomy Section of Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur (M.S.), India during *kharif,* 2019. The experiment was laid out in a split plot design with four replications and nine treatment combinations comprising of three varieties V_1- Indrayani, V_2- Phule Radha and V_3- Bhogawati as main plot treatments and three fertilizer levels F_1- 75% RDF, F_2- 100% RDF and F_3- 125% RDF as sub plot treatments on sandy clay loam soil. The growth parameters at harvest *viz.*, numbers of tillers m^{-2} (373.59), number of functional leaves $plant^{-1}$ (29.24), leaf area $plant^{-1}$ (9.62 dm^2) and dry matter production $plant^{-1}$ (28.68 g) were significantly more with the variety Indrayani and which was remain at par with Bhogawati and significantly superior over Phule Radha except for plant height. The plant height at harvest was significantly more with the variety Phule Radha (90.42 cm) and which was found at par with Indrayani (87.46 cm) which was superior over Bhogawati (84.07 cm).

Keywords: Variety, fertilizer levels, growth contributing characters

Introduction

Among cereals, rice is the staple food for more than 60 per cent of the world population, providing energy for about 40% of the world population where every third person on earth consumes rice every day in one form or other (Virdia and Mehta, 2009) [45]. Therefore, crop paddy (*Oryza sativa* L.) is an important crop which is extensively grown in tropical and subtropical regions of the world. The worldwide paddy production in 2019-20, China was the leading country with a production of 146.73 million metric tonnes followed by India with 115.00 million metric tonnes (Anonymous, 2020) [4]. In India major growing states are West Bengal, Tamilnadu, AP, Kerla, Goa, KN Orissa, Punjab. Paddy is cultivated in India in a very wide range of ecosystems from irrigated to shallow lowlands, mid-deep lowlands, and deep lowlands to uplands. In Maharashtra state coastal region *i.e.* Konkan is the major rice belt comprising Ratnagri, Raigad, Sindudurg and Thane districts. Whereas, Western Maharashtra districts *i.e* Satara, Sangli and Kolhapur and Bhandara, Gondiya, Chandrapur and Gadchiroli in the Eastern Parts of the state are minor paddy growing districts. Transplanting is the major method of paddy cultivation in India and Maharashtra state. However, transplanting is becoming increasingly difficult due to shortage and high cost of labour, scarcity of water, and reduced profit. Thus, direct seeding is gaining popularity among farmers of India as in other Asian countries. Direct-seeding constitutes both wet and dry seeding and it does away with the need for seedlings, nursery preparation, uprooting of seedlings and transplanting. In Sub Montane Zone of Maharashtra and especially in Kolhapur district, it is mostly grown by transplanted method; however, there are some of the pockets, where direct seeding and dibbling is practiced. Transplanted-flooded rice consumes more than 50 per cent of the fresh water resources that are diverted for human uses. Groundwater tables have fallen in the major rice-growing countries. In the Indian states of Punjab, Haryana, Gujarat, Tamil Nadu, Rajasthan Maharashtra, and Karnataka, it is falling at 0.5–2.0 m per year (Singh and Singh, 2002) [38]. However, in recent years, depleting water resources governed by climate change and labor shortage are threatening the sustainability and productivity of transplanted-flooded rice. In Asia, 39 million ha of irrigated rice may suffer from "physical water scarcity" or "economic

Water scarcity" by 2025 (Tuong and Bouman, 2003) [42]. Compared with other cereal crops such as wheat and maize, transplanted-flooded rice consumes two or three times more water. Transplanted-flooded rice leads to high losses of water through puddling, surface evaporation and percolation (Farooq *et al.*, 2011) [11]. Puddling in transplanted-flooded rice systems consumes up to 30% of the total rice water requirement (Chauhan and Opena, 2012) [6]. Although, puddling is favorable in rice–rice cropping systems, as it reduces soil permeability, creates hardpans and reduces water losses through percolation. Nonetheless, repeated puddling operations negatively affect the following non-rice upland crop in rotation (McDonald *et al.*, 2006) [26] by dismantling soil aggregates, reducing permeability in subsurface layers, and forming hardpans at shallow depths (Sharma *et al.*, 2003) [36]. Taking the advantages of saving water and labor and increasing system productivity, dry direct-seeded rice has been believed to be an optimal option for rice production (Kumar and Ladha, 2011) [21]. Dry direct-seeded rice refers to the process of establishing the crop from seeds sown in the non-puddled and unsaturated soil; in contrast, the seedlings from nursery are transplanted in the puddle soil in transplanted-flooded rice. Dry direct-seeding is adopted in upland rice and aerobic rice. In the past decades, numerous researchers worldwide have dealt with yield performance and water use efficiency or water productivity (WP) of dry direct-seeded rice, but they reported variable yield response depending upon location and type of cultivar.

Good seed quality and seedling vigor are desirable for optimal establishment of a DSR crop, and also for weed competitiveness. Seedling vigor is defined as the ability of a plant's aerial part to emerge rapidly from soil or water. Rapid germination, rapid shoot and root growth, and long mesocotyls and coleoptiles are important seedling vigor-related traits (Cui *et al*., 2002; Redona and Mackill, 1996) [7, 33]. All these traits will favor seedling establishment in direct seeding. For example, rapid germination and rapid shoot development are likely to help in avoiding submergence stress. A longer mesocotyl will minimize sensitiveness to seeding depth in drill seeding and improve seedling establishment. The modern semi-dwarf cultivars have a short mesocotyl, and this is disadvantageous for good CE, especially when seeds are drilled deeper in the soil (Dilday *et al*., 1990; Fukai, 2002) [9, 13]. In the absence of precise land leveling and precise seeding machinery, it is difficult to achieve precise placement of seeds at shallow depth. Therefore, a suboptimal sowing depth leads to poor CE. Moreover, in conservation tillage systems in which residue is mulched, emergence of the crop may be adversely affected because of short mesocotyl.

Rice characteristics reported to be associated with weed competitiveness include (a) plant height together with early and rapid growth rate, (b) higher tiller number, (c) droopy leaves, (d) relatively high biomass accumulation at the early stage, (e) high leaf area index and high specific leaf area during vegetative growth, (f) rapid canopy ground cover and (g) early vigor. However, all these traits are found better in direct seeding rice cultivation as compared to transplanted rice cultivation. (Kumar and Ladha, 2011) [21]. It is argued that the introduction of some of these traits in a variety may result in some yield loss (Dingkuhn *et al*., 1999; Perez de Vida *et al*., 2006) [10, 31]. However, it is also argued that the benefit of having these traits is likely to be higher than when not having them (Fischer *et al*., 2001; Gibson *et al*., 2003; Zhao *et al*., 2006) [12, 14, 49]. Although tall plants are linked to weed competitiveness, they often have low yield potential and tend to lodge. Semi-dwarf varieties can be as competitive as tall plant-type varieties. Therefore, shorter intermediate height (between tall traditional and modern semi-dwarf) may be more desirable for direct seeding (Fukai, 2002) [13]. Unlike an initial shock in transplanting that delays tillering, tillering does not seem to be a constraint in direct seeding. Therefore, tillering ability is not a primary trait for selection (Fukai, 2002; Song *et al*., 2009) [13, 40]. In fact, Song *et al*. (2009) [40] reported that excessive tillering at an early stage could result in reduced leaf biomass and photosynthesis at a later stage and eventually become one of the major reasons for lower yields. *Oryza glaberrima*, a cultivated rice with low yield potential, possessing the trait of droopy leaves with high specific leaf area, is very effective in weed suppression. Jones *et al*., (1997) [17] suggested that, if this trait is restricted to early growth and combined with the trait of erect leaves with low specific leaf area from *O. sativa*, this can be useful for direct seeding.

A slower crop growth rate during the reproductive phase has been reported to be associated with poor spikelet fertility, which is a most commonly observed characteristic in direct seeding. Horie (2001) [15] reported that crop growth rate during the 2-week period preceding full heading determines yield through effects on spikelet number, single-grain mass, and potential grain-filling. The rice plant enters the reproductive phase about 1 month before anthesis and generally differentiates excess spikelets depending on previous N uptake. Spikelets then degenerate during this 2-week period preceding full heading depending on the availability of carbohydrates (Wada, 1969) [46]. Kato and Katsura (2010) [18] observed that the frequency of floret abortion was associated with biomass production during the reproductive phase. This suggests that, in order to achieve high panicle fertility, sink demand should be met by high canopy photosynthesis at pre-anthesis and high remobilization ability. Causes of low crop growth rate during the reproductive phase in direct seeding may be attributed to (a) high biomass during the vegetative phase and thus more maintenance respiration, (b) low foliar N concentration, and (c) reduced canopy CO_2 assimilation rates (Yoshida, 1981). The low growth rate during the reproductive phase of direct-seeded rice leads to its earlier senescence than transplanted rice. Thus, a plant type with erect leaves having low specific leaf area (higher biomass per unit area) and high chlorophyll content (Dingkuhn *et al*., 1999) [10], which is likely to increase the crop growth rate during the reproductive phase and prolong the ripening phase has desirable characteristics for direct seeding. Katsura *et al*., (2010) [19] found higher yield in direct-seeded aerobic rice than in puddled transplanted rice because of high N accumulation during the ripening phase. Thus, the ability to enhance N uptake during the ripening phase, which is a prerequisite to enhancing canopy photosynthesis and assimilate supply, is equally important to be considered in a breeding program for direct seeding (San-oh *et al*., 2004) [35]. In addition, direct-seeded rice cultivars must possess enhanced assimilate export ability from the vegetative parts to reproductive parts during the reproductive phase.

Relatively little work has targeted selection and breeding of rice for direct seeding, especially under zero tillage in Asia. Generally, rice varieties bred for puddled transplanting are used in direct seeding. The lack of suitable varieties is a major constraint to achieving maximum potential of direct seeding. The traits that are likely to be most helpful for direct seeding include (1) anaerobic seed germination and tolerance of early submergence for quick CE, (2) high seedling vigor with faster leaf area development (semi-erect leaves with high specific leaf area) during the early vegetative stage for weed suppression, (3) erect leaves with low specific leaf area and high chlorophyll content for high crop growth during the reproductive phase along with high remobilization ability for higher spikelet fertility, (4) astrong, thick, and sturdy culm with long and heavy panicles positioned at lower height for lodging resistance, and (5) high genetic yield potential with high input use efficiency under DSR (Kumar and Ladha, 2011) [21].

In the sub-montane zone of Maharashtra and specially in Kolhapur district, there are several paddy cultivars developed by the Agriculture University and Private Seed Companies which are used by the local farmers for puddle transplanted paddy cultivation. But, there are no any cultivar developed for dry seeded condition and for other direct seeding methods under rainfed condition. The promising and popular varieties famous among the farmers developed by Agriculture University are therefore selected to study the yield potential for different fertilizer doses in dry direct seeded paddy cultivation. The research study will be helpful for choosing the suitable varieties and fertilizer doses for getting higher optimum yield in dry seeding condition. Major paddy growing areas in the region are highly sandy clay loams. Poor fertility and low moisture holding capacity are the characteristics of these soils. Fertilizer input is one of the major determinants of the profitability of the paddy grown on these soils. Fertilizer use efficiency is low in the region due to heavy rainfall and it is revealed from the studies that use of different fertilizers improves fertilizer use efficiency (Tondon, 1992) [44]. The information on nutrient requirements of the crop to be supplied through straight fertilizers is available. However, the information on requirement of nutrients in paddy established by comparing different fertilizer sources is lacking. Thus, farmers' adoption for a variety becomes different as the performance of the variety under suboptimal nutrient conditions is least as important as their performance under optimal nutrient supplies.

Materials and methods

The experiment was laid out in a split plot design with four replications and nine treatment combinations comprising of three varieties V_1- Indrayani, V_2- Phule Radha and V_3- Bhogawati as main plot treatments and three fertilizer levels F_1- 75% RDF, F_2- 100% RDF and F_3- 125% RDF as sub plot treatments. The gross and net plot size were 6.00 m x 4.5 m and 5.00 m x 3.6 m, respectively. A spacing of 22.5 cm was adopted in seed sowing between two rows. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (pH 7.70), having electrical conductivity 0.28 dS m^{-1} and organic carbon content was very low (0.18%), low in available nitrogen (254.90 kg ha^{-1}), medium in available phosphorus (28.70 kg ha^{-1}) and high in available potassium (276.20 kg ha^{-1}).

The crop was sown on 3rd of June, 2019 by line sowing method with different varieties and fertilizer levels. The paddy crop was fertilized treatment wise as per different fertilizer levels. The fertilizers were applied at the time of sowing of paddy seed, 40 per cent nitrogen, and full dose of P_2O_5 and of K_2O was applied as basal dose. The remaining 60 per cent nitrogen was applied in two splits; 40 per cent at maximum tillering stage i.e. 30 DAS and 20 per cent at 60 DAS. Nitrogen was applied through urea (46% N), P_2O_5 through Diammonium phosphate (18:46:00), K_2O through Muriate of Potash (60% K_2O).

Growth characters determination: For studying the effect of various treatments on the plant characters, biometric observations *viz.,* plant height; number of tillers m^{-2}, number of functional leaves $plant^{-1}$, leaf area $plant^{-1}$ and dry matter accumulation $plant^{-1}$ were recorded at a regular interval of 15 days throughout the life period of the paddy crop. Five plants were selected randomly for recording various periodical observation and tagged in each treatment net plot.

Statistical analysis: The statistical analysis of split plot design with with 4 replications, 3 main plot treatments and 3 sub-plot treatments was done by standard procedures suggested by Panse and Sukhatme (1967) [28].

Result and discussion

I) Effect on plant height of paddy (cm)

A. Effect of varieties

The variety Phule Radha produced significantly maximum plant height and found at par with variety Indrayani. While, the variety Bhogawati produced significantly lowest plant height at harvest. However, Similar experimental findings revealed that height of the plant, being a varietal character, was found to differ significantly among the cultivars earlier reported by Amarasinghe *et al*., (2014) [2], Patel and Mishra (2015) [30], Kumar *et al.*, (2017) [22] and Riste *et al.*, (2017) [34].

B. Effect of fertilizer levels

Application of 125% RDF recorded significantly higher plant height and remained at par with application of 100% RDF. While, significantly lowest plant height was produced with the application of 75% RDF at harvest. Plant height increased with increasing levels of fertilizer up to maximum level of fertilizer application and it was directly proportional to same. The increase in plant height was observed in the experiment may be due to the favorable effects of fertilizer – metabolism and consequently on the vegetative growth of paddy plant (Kumar *et al*., 2007) [20]. Similar findings were also reported by Anand *et al*., (2018) [3], Patel and Mishra (2015) [30], Mane *et al*., (2012) [25] and Bhagat *et al*., (2005) [5].

C. Interaction effect

The interaction effect between different varieties of paddy at different fertilizer levels was found non-significant in respect of mean plant height of paddy.

II) Effect on number of tillers m^{-2}

A. Effect of varieties

The variety Indrayani produced significantly maximum number of tillers m^{-2} and found at par with the variety Bhogawati at harvest. The significantly minimum numbers of tillers m^{-2} were produced by the variety Phule Radha. Similar results were also reported by Anand *et al*., (2018) [3], Dangi (2016) [8], Patel and Mishra (2015) [30], Shukla *et al*., (2015) [37] and Kumar *et al*., (2007) [20].

B. Effect of fertilizer levels

The numbers of tillers m^{-2} was increased with increasing levels of fertilizer. Application of 125% RDF recorded significantly maximum number of tillers m^{-2} which was at par with the application of 100% RDF while the minimum numbers of tillers m^{-2} were produced with application of 75% RDF at harvest but it was remained at par with application of

100% RDF which means it is directly proportional to fertilizer levels. Kumar *et al*., (2017) [20], Dangi (2016) [8], Shukla *et al*., (2015) [37], Patel *et al*., (2014) [29] and Kumar *et al*., (2007) [20] recorded similar findings in collaborative with present findings.

C. Interaction effect

The variety Indrayani applied with 125% RDF has recorded significantly higher number of tillers m^{-2} at harvest (379.22). Amarasinghe *et al*., (2014) [2] and Suryavanshi (2015) [41] reported the same results.

Table 1: Growth characters of paddy at harvest as influenced by different treatments

Treatments	Plant height (cm)	Number of tillers m^{-2}	Number of functional leaves $plant^{-1}$	Leaf area $plant^{-1}$ (dm^2)	Dry matter production $plant^{-1}$ (g)
Main plot : Paddy varieties					
V_1- Indrayani	87.46	373.59	29.24	9.62	28.68
V_2- Phule Radha	90.42	359.96	23.69	8.80	25.00
V_3- Bhogawati	84.07	369.51	27.94	9.55	27.00
S. Em±	1.26	4.09	0.77	0.26	0.76
C. D. at 5%	4.51	12.11	2.66	0.81	2.63
Sub plot : Fertilizer levels					
F_1 - 75% RDF	84.64	362.81	23.08	9.07	20.36
F_2 -100% RDF	87.46	268.20	28.16	9.42	29.41
F_3 - 125% RDF	89.33	372.04	29.64	9.48	30.92
S. Em±	1.34	3.03	0.73	0.12	0.70
C. D. at 5%	3.98	8.84	2.16	0.38	2.07
General mean	87.34	367.69	26.96	9.33	26.89

III) Effect on number of functional leaves $plant^{-1}$

A. Effect of varieties

The variety Indrayani produced significantly maximum number of functional leaves $plant^{-1}$ at harvest and found on par with the variety Bhogawati. However, at harvest the variety Phule Radha produced significantly minimum number of functional leaves $plant^{-1}$. The findings were in conformity with earlier reported in paddy varieties by Dangi (2016) [8], Riste *et al*. (2017) [34] and Amarasinghe *et al*., (2014) [2].

B. Effect of fertilizer levels

Application of 125% RDF recorded significantly maximum number of functional leaves $plant^{-1}$ which was at par with the application of 100% RDF and the significantly minimum number of functional leaves $plant^{-1}$ was produced with application of 75% RDF at harvest. It is directly proportional to levels of fertilizer. These findings were in conformity with earlier reported by Amarasinghe *et al*., (2014) [2], Dangi (2016) [8] and Riste *et al*. (2017) [34].

C. Interaction effect

The variety Indrayani applied with 125% RDF has recorded the maximum number of functional leaves $plant^{-1}$ at harvest (34.03) over rest of the remaining treatment combinations except it was at par with 100% RDF having number of functional leaves $plant^{-1}$ at 60 DAS (26.69) and 75 DAS (28.35).

Table 2: Effect of interaction on growth characters of paddy at harvest

Treatment combinations	Plant height (cm)	Number of tillers m^{-2}	Number of functional leaves $plant^{-1}$	Leaf area $plant^{-1}$ (dm^2)	Dry matter production $plant^{-1}$(g)
V_1F_1	85.60	368.70	23.50	9.30	21.31
V_1F_2	86.75	372.86	30.19	9.73	30.48
V_1F_3	90.06	379.22	34.03	9.86	34.37
V_2F_1	88.31	354.11	19.09	8.52	16.56
V_2F_2	90.44	361.00	26.01	8.95	29.17
V_2F_3	92.43	364.80	26.00	8.95	29.29
V_3F_1	80.03	365.65	26.65	9.42	23.22
V_3F_2	85.21	370.77	28.29	9.61	28.68
V_3F_3	87.00	372.11	28.90	9.65	29.11
S. Em±	2.33	1.86	1.26	0.04	1.21
C. D. at 5%	NS	6.23	3.74	0.12	3.58
General mean	87.34	367.69	26.96	9.33	26.89

IV) Effect on leaf area $plant^{-1}$ (dm^2)

A. Effect of varieties

The significantly higher leaf area was recorded by the variety Indrayani as compared to other varieties. However, it was on par with the variety Bhogawati. The variety Phule Radha recorded minimum leaf area $plant^{-1}$ at harvest. Similar findings were reported by Zayed *et al*., (2010) [48] and Abou-Khalifa (2012) [1].

B. Effect of fertilizer levels

The leaf area $plant^{-1}$ was significantly influenced by the application of 125% RDF at harvest and remained on par with 100% RDF. The lowest mean leaf area $plant^{-1}$ was observed with application of 75% RDF but it was remained at par with 100% RDF. Mean leaf area $plant^{-1}$ increased with increasing levels of fertilizer up to maximum level which is directly proportional to fertilizer levels. Somasundaram *et al*., (2002) [39], Zayed *et al*., (2010) [48], Abou-Khalifa (2012) [1], Tomar *et al*. (2018) [43] reported same results.

C. Interaction effect

The variety Indrayani fertilized with 125% RDF has recorded the higher number of leaf area $plant^{-1}$ harvest (9.86 dm^2) over rest of the remaining treatment combinations. However, at 45 DAS it was remained at par with 100% RDF.

V) Effect on dry matter production plant^{-1} (g)

A. Effect of varieties

The variety Indrayani recorded significantly more dry matter under study and remained at par with the variety Bhogawati, while the variety Phule Radha accumulated significantly less dry matter but remained at par with Bhogawati at harvest. Dry matter accumulation is mainly affected by crop growth factors. Cultivars having more and well developed vegetative growth produces more dry matter accumulation. Kumar *et al.*, (2019) [23], Zayed *et al*., (2010) [48], Mendhe *et al*., (2006) [27], Kumar *et al*., (2007) [20], and Pillai (2004) [32] found similar research findings.

B. Effect of fertilizer levels

The dry matter production plant^{-1} was recorded significantly higher with application of 125% RDF at harvest and found at par with application of 100% RDF, while significantly lowest mean dry matter production plant^{-1} was observed in 75% RDF treatment. It means the dry matter accumulation plant^{-1} is directly proportional to fertilizer levels. However, Kumari *et al*., (2000) [24], Somasundaram *et al*., (2002) [39], Zayed *et al*., (2010) [48], Mane *et al*., (2012) [25], Patel *et al*., (2014) [29] and Javeed *et al*., (2017) [16] observed more dry matter accumulation by the application of higher doses of fertilizer levels and dry matter production also increased with increased levels of inorganic nitrogen.

C. Interaction effect

The variety Indrayani applied with 125% RDF has recorded significantly higher dry matter production plant^{-1} at harvest (34.37 g). However, the results are in conformity with earlier reported by Zayed *et al*., (2010) [48].

Conclusion

Based on the present investigation of one year data the following conclusions could be drawn:

1. Among the varieties, Indrayani as well as Bhogawati recorded higher growth characters and therefore both varieties are suitable for gaining more growth and development in Sub Montane Zone of Maharashtra and in Kolhapur district.
2. Among the fertilizer levels tried, the application of 100% RDF ha^{-1} and 125% RDF ha^{-1} is suitable for more growth and development of paddy.
3. Among the interaction combinations, paddy variety Indrayani applied with 125% RDF ha^{-1} recorded highest growth and development than rest of the treatment combinations.
4. Paddy variety is highly responsive to higher doses of fertilizer levels so, 125% RDF ha^{-1} can be recommended for better growth and development.

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