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DROUGHT MANAGEMENT IN UPLAND RICE-A REVIEW

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Abstract

Rice (*Oryza sativa* L.) is one of the most ancient crops being cultivated in 117 countries. It is the main item of the diet of 3.5 billion people, but the productivity of rice in India is low due to a number of factors like soil moisture stress, delayed sowing, heavy weed infestation, poor native soil fertility status and poor spread of improved upland cultivars have been identified as important constraints in realization of enhanced productivity levels under rainfed upland situations. The major cause of un-suitability of upland rice is due to mismatch between the environment rhythm especially rainfall pattern and crop growth rhythm. Manipulation of sowing time may help the crop to avoid the coincidence of stress at critical period. Considerable genetic variations exist in upland rice varieties with respect to their morphological traits which enable them to escape, tolerate or resist and recover from moisture stress. Poor crop stand due to improper seed placement, insufficient soil moisture for germination and severe weed competition is the major bottleneck in upland rice production. Moisture stress at initial stage adversely affects the emergence of seedlings. Seed hardening or priming is a low cost technique to avert the soil moisture stress at initial stage. Split application of nitrogen helps the crop to sustain yield in weather abberations and tide over moisture stress.

Key words: Moisture stress, Upland rice, Sowing time, Weed competition, Split application

Introduction

Rice (*Oryza sativa* L.) is a major food of the world and more than half of the population subsists on it, hence called as "Global Grain". In India it is grown over an area of 44.1 m ha with a total production of of 105m t and a productivity of 2393 kg/ha (CMIE, 2012). A number of factors like soil moisture stress, delayed sowing, heavy weed infestation, poor native soil fertility status and poor spread of improved upland cultivars have been identified as important constraints in realization of enhanced productivity levels under rainfed upland situations (Mishra, 1999) The defining feature of rain fed upland rice ecosystem is the lack of ponded water at any time during the life cycle, so soils remain aerobic throughout where establishment of rice is risky (Wade, 2003). The major problems limiting productivity of upland rice are moisture stress, weed infestation and nutrient deficiency (IRCN, 1985). Among these, drought induced moisture stress has been identified as the major yield depressant of upland rice crop in Eastern India which constitutes about 85% of total upland rice area in India (Widawsky and O'Toole, 1996). About 70% of upland rice area in India are drought prone (Singh, 2002). Productivity of the crop fluctuates drastically from year to year due to vagaries of south-west monsoon, occurrence of dry spells and moisture deficit during growing season. Occurrence of dry spell of varying intensity at different growth stages of upland rice resulting in even complete failure is not uncommon. However, the effect of the stress is not equal throughout the life cycle of the crop (O' Toole and Chang, 1978; Widawsky and O' Toole , 1996; Saini and Westgate, 2000). Choice of suitable variety , optimum sowing time, proper seed treatment and time of nitrogen and potassium application are some of the options to mitigate the adverse effect of moisture in rainfed uplands Liming may result in efficient utilisation of residual moisture because of better root development of the crop. In this paper an attempt has been made to review the relevant research works done in India and abroad.

1. Drought

Agricultural drought is defined as a period or periods during the life cycle of the crop when supply of water is too small to meet the evaporative demand for sufficiently long that the reduction in yield is economically

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unacceptable. Drought occurs mostly due to the variation in quantity and distribution of rainfall. Initial, terminal and intermittent droughts during crop growing period result due to a delay in onset, early withdrawal and intermittent breaks in south-west monsoon in India. Occurrence of these types of droughts affecting upland rice is very common. The date for onset and withdrawal of monsoon also dictates the length of the crop growing season which helps selection of crops and their varieties of optimum duration for a locality. Rainfall analysis at Raipur, India depicted that average productivity of upland rice decreased from 1.2 t/ha under early onset to 0.8 t/ha under late onset of monsoon due to the decrease in moisture availability period (Sastri, 1986).

Agricultural drought being a complex phenomenon involving dynamic interchanges within soil-plant atmospheric continuum, the duration of stress period to affect yield of upland rice varies from region to region. At Bhubaneswar, Orissa under drying condition assuming 20 mm minimum rainfall to meet the crop water requirement per week, the safe weeks for growing upland rice (90d) are from 25 (18-24)to 40 (1-7 October) meteorological week covering a period of 16 weeks at 70 per cent probability level (Garnayak, 1987). Upland rice maturing in about 90 days can be grown safely with 12 such safe weeks. Later, Lenka and Garnayak (1991) on physic al verification of daily rainfall data at Bhubaneswar considered failure of rainfall for more than five days as stress period for upland rice. Out of ten years, stress occurred in seven years at post germination and tillering stage and for five years each between panicle initiation to flowering and flowering to ripening period. Total number of stress days coinciding with almost all growth stages of the crop was even 33 during the severe drought year, 1987.

Rainfall analysis at Hazaribag, Jharkhand indicated that occurrence of dry spell of five days duration is expected every year, of two weeks duration in alternate years and extreme spell of 34 days or more is very rare (Singh *et al*., 1996). It is estimated that dry spell of five to nine days duration in each monsoon month occurred in more than five years out of 10 while that of 20-24 days in less than one year out of 10 in these months in India (Murty, 1987). In Chhotanagpur plateau of Bihar, upland rice experienced dry spells of 5-12, 0-10 or 5-23 days duration coinciding with both the vegetative and reproductive growth stages (Mishra *et al*., 1996), Pathak *et al.* (1999) opined that direct seeded upland rice in many rice growing areas is characterised by moisture deficit for much of the crop growth period.

2 . Moisture stress vs. Growth stages of upland rice

Upland rice is defined most widely as a rice grown in rainfed well drained soils without surface water accumulation and phreatic water supply and normally not bunded (CRRI, 2000). Crop growing season under upland situation is always greater than the length of rainy season and is dependant not only on rainy season but also on water availability periods and the soil characteristics (Singh *et al.* 2002). Since greater portion of the life cycle of upland rice crop is spent in dry regime and about 90 per cent roots lie in top 10 cm layer (Jaggi and Bisen, 1984), rainfall in small quantity much less than the evaporative demand of the atmosphere very frequently results in failure of the crop.

Of course, the extent and nature of damage, the capacity for recovery and the impact on yield depend on the stages at which the crop encounters the stress (O' Toole and Chang, 1978). In general, the reproductive stage is more vulnerable to moisture deficit than vegetative one (Jones, 1981; O' Toole and Moya 1981; Garrity *et al*., 1986; Widawsky and O' Toole, 1996; Saini and Westgate, 2000).

Initial drought adversely affected the germination and crop stand of upland rice. Rice seeds have to imbibe water at the rate of 25 to 35 per cent of its weight for germination. Therefore, screening of seeds for germination under osmotic stress of 0.5 MPa was found to be useful for soil moisture at germination (Murty, 1987). Soil moisture potential between -0.05 to -0.20 MPa was most favourable for seedling emergence (Jaggi and Bisen, 1984). Soil moisture content at 50 to 75 per cent field capacity and soil moisture potential above -0.6 MPa was optimum for germination of rice seeds in a sandy loam soil. Due to moisture deficit at initial crop growth stage rice seedlings failed to emerge even until 13 days after sowing (Pathak *et al*., 1999).

Stress at early seedlings and tillering stages was manifested either in wilting or drying of leaves, which directly affect plant stature, tillering and source intensity. Tillers produced till the end of vegetative phase drought (30-50 days after sowing, DAS) contributed substantially to grain yield of upland rice varieties but not the later formed ones (Bhattacharjee *et al*., 1973; Ramakrishnayya and Swain (2002) reported that increase in severity of vegetative stage (21 to 35 DAS) stress, decreased the water potential and relative water content of leaves. Later, Ramakrishayya and Swain (2002) reported that leaf and culm dry matter at flowering was more under induced soil moisture stress (21-49 DAS) but panicle weight was considerably lower resulting in less total dry matter indicating the adverse effect of soil moisture stess on translocation of photosynthates from shoot to panicle. Leaf elongation rate of rice was more sensitive to water deficit than leaf rolling (Lilley and Fukai, 1994). Lenka and Garnayak (1991) reported that prolonged stress at earlier phases of growth increased crop duration more than that at later stage.

Stress during panicle development to flowering was more harmful (r = -0.78*) and irreversible than that at sowing to panicle initiation (r = -0.18) and ripening (r = -0.20)stages of growth (Lenka and Garnayak, 1991). Chauhan *et al*. (1999) stated that soil moisture stress of 8 days duration at booting and anthesis stages of two rainfed upland rice cultivars Browngora and Vandana reduced plant height, leaf area, total dry matter per tiller and panicle weight. Stress during reproductive phase of cereals can delay or completely inhibit flowering (Saini and Westgate, 2000). Pollen sterility, failure of pollination, spikelet death or zygotic abortion occur due to stress during flowering and early grain initiation. Stress during early grain development curtails the kernel sink potential by reducing number of endosperm cells and amyloplasts formed and also causes premature cessation of grain filling. All of these adverse effects culminated in reduced grain yield. Terminal drought occurring at 100-102 DAS resulted in substantial rolling, senescence and drying of leaves of 54 upland rice genotypes at Jagdalpur, Chhattisgarh. But the intensity was higher in low yielding than high yielding genotypes (Agarwal and Khan, 2002). Moisture stress at flowering due to scanty rainfall greatly reduced the yield of upland rice in middle and south Gujrat (Pathak *et al*. 2002).

3. Date of sowing

One of the major hindrance to yield stability of promising upland rice varieties under unpredictable drought condition is narrow flexibility of sowing period (Ghosh, 2002). Sub- optimal plant population as a result of untimely sowing has been identified as one of the limiting factors of yield in upland rice.

Early sowing of rice ensures more rainfall during seedling to grain filling stage than late sowing and helps the crop to escape the terminal drought (Behera *et al*., 1997; Mohapatra *et al*., 1997). Effectiveness of rainfall during crop growing season also decreased from 78 per cent for 6 June sown crop to 67 per cent in 30June sown one at Bhubaneswar (Garnayak, 1987). Subsequently, Kebede (2000) also confirmed this finding and the crop sown on 5 June escaped reproductive stage stress. It was seen that a gap of four weeks or more between dry seedling and receipt of rains substantially reduced the yield at Cuttack (Prasad and Rao, 1985). Later Dinesh Chandra *et al*. (1991) reported that crop stand and yield were adversely affected due to inadequate soil moisture under dry seedling in May. Many other workers have also reported either significantly higher (Sekhar and Singh, 1991; Pravakar and Reddy, 1997) or at par yield (Garnayak, 1987 and Kebede, 2000) of mid June sown crops as compared to either May last of June first week sown one.

Optimum sowing time for rainfed upland rice in coastal Orissa was between 5 to 15 June. The crop can be sown in second fortnight of June as about 200 mm rainfall is received in June at 90 per cent probability. Advanced sowing in May affected yield adversely due to inadequate soil moisture while delayed sowing beyond 25 June reduced crop stand and yield (Rao, 1983). This finding was confirmed by results conducted at Central Rice Research Institute, Cuttack (CRRI, 1987, 1988, 1990). Delayed sowing beyond 25 June adversely affected growth of rice seedlings, plant stand and yield due to sudden and heavy rain, inadequate weed control and adverse effect of terminal drought (Singh *et al*., 1984; Prasad and Rao, 1985; Dinesh Chandra *et al*., 1991; Behera *et al*., 1997; Kebede, 2000). It was further observed that reduction in grain yield due to delayed sowing from 15 June to 3 July got aggravated in the season when rainfall warned off by the end of September resulting in reproductive stage stress. Delayed sowing beyond normal date in general increased sterility of spikelets (Garnayak, 1987; Ghosh *et al*., 1988; Sekhar and Singh, 1991; Pravakar and Reddy, 1997; Kebede, 2000; Roul and Kundu, 2002). Earlier sown crop on mid June removed significantly higher amount of N, P and K in both grains and straw than the late sown crops on first fortnight of July under Bhubaneswar conditions (Khatua, 2002). She has also reported higher consumptive use and water use efficiency by early sown crops.

4. Variety

Use of improved variety contributes up to 40 per cent towards the productivity of upland rice (Bujarbaurah *et al*., 2002). Morpho-physiological traits such as duration, tilllering , leaf area, rooting ability, panicle characteristics, biomass production ability, plant water status etc. to withstand drought varied with rice varieties (Chang *et al*.,1974; Rao and Venkateswarlu, 1998; Agarwal and Khan, 2002).In evaluating upland rice genotypes for drought resistance the four underlying physiological mechanisms *i.e.* escape, avoidance, tolerance and recovery are generally referred to (Levitt, 1972; Chang *et al*., 1974).

For drought escape mechanism, first priority is placed on early maturity because of its simplicity and high heritability(Maurya and O'Toole, 1986). Moreover, medium duration varieties were more affected by moisture stress at flowering and milk stages, whereas short duration varieties escaped the stress at these stages (Sheela and Alexander, 1995). Agarwal and Khan (2002) also reported that early maturing upland rice genotypes partially escaped terminal drought Jeena and Mani (1990) opined that apart from high root density and root weight, the duration of the crop was very important for selecting drought tolerance genotypes.

A deep root system is an important component of drought resistance because it enables the plants to exploit water from deeper soil layers.Drought resistant upland rices have few but thick roots that penetrate to deeper layers during soil drying (Namuco *et al*., 1993). Traditional varieties were more tolerant to drought at reproductive stage than high yielding ones due to their higher seedling survival and vigour, lower transpiration index, consistently higher water potential in plant tissues, lower chlorophyll stability index, higher root to shoot ratio and efficient partitioning of dry matter into reproductive sinks even under drought conditions (Swamy *et al*., 1983; Maurya and O'Toole, 1986; Swamy and Reddy, 1988; Swamy and Murthy, 1993). Susceptible cultivars showed decreased germination percentage, reduced root lengths, leaf area and stunted growth as compared to the resistant cultivars (Akomeah *et al*., 1995).

Mishra (1999) reported that an ideotype of rice for upland conditions should have larger panicles, biological yield and straw weight coupled with more tillers per plant and large number of grains per panicle. Rice varieties with medium stature, moderate number of panicles/ m^2 and higher number of filled spikelets per panicle were superior to others under rainfed upland ecosystem (Rao and Shrivastav, 1999). Ramakrishnayya and Swain (2002) recorded least reduction in yield (10%) of rice culture CR 143-2-2 as compared to others (50-80%) because of the possible existence of osmotic adjustment resulting in little impaired translocation of photosynthates from shoot to panicle.

On farm trials in drought prone Kalahandi district of Orissa revealed that Vandana, CR 666-110, CR 666-78 and Kalinga III rice cultures were most suitable for rainfed unbunded uplands (Behera *et al*., 1997) and Pathara, Vabaprabha and CR 666-78 for bunded uplands (Behera and Jha, 1998). The farmers preferred to early varieties having semi tall stature, drought tolerance good cooking quality, better performance at low nitrogen levels and free from gundhi bug and blast infestation. In the eastern ghat regions of Orissa, rice variety Shankar was more promising than Parijat, Subhadra, Annada and Pathar (Padhi, 1995). In upland rice ecosystem of coastal tract in Orissa , rice variety Annada was superior to Annapurna and Chiana (Dinesh Chandra *et al*., 1991) and Heera NX (Saha *et al*., 1999) Roy (1993) and Mohapatra *et al*., (1997) reported the superiority of super fast rice variety Heera and Kalyani II under upland conditions. ZHU XI-26 maturing in 80-85 days performed better than Kalinga III or Vandana (90-95 d) at Bhubaneswar (Kebebe, 2000; Khatua, 2002).

5. Method of sowing

Selection of appropriate method of seedling is important to ensure adequate plant stand to economise on seed rate, to assure minimal chances of seedling mortality due to drought and to facilitate weed control. Farmers ensure adequate plant stand and easy mechanical weeding with line sowing over broadcasting (Dixit *et al*., 1979). Irrespective of seed rates, sowing in rows recorded 34 per cent higher plant population after 10 days of sowing over the broadcast method of sowing. This in turn increased yield from 1.5 t/ha in broadcasting to 1.8 t/ha in row sowing (Tosh *et al*., 1981). Ananda *et al*. (2002) reported higher grain yield with seed drilling than broadcasting as the broadcast crop was more prone to lodging.

Seeds dibbled or continuously sown behind the plough were generally placed at 5-6 cm depth as against 2-3 cm in case of broadcasting or drilling. Deeper placement of seeds behind the plough resulted in uniform plant stand, better drought tolerance and higher yield than latter cases (Dinesh Chandra *et al*., 1991; Singh *et al*., 1999). Subudhi *et al*. (1993) at Phulbani , Orissa reported higher grain yield of 5.5 t/ha in case of sowing behind the plough over broadcasting (1.5 t/ha) due to deeper placement of seeds (3 cm) resulting in 43 per cent higher plant population per m^2 in the former. Sinha *et al*. (1996) at Hazaribag, Bihar obtained similar grain yields by drilling 60-80 kg seeds/ha behind the plough at a row distance of 20 cm to that by broadcast sowing of 90-100 kg seeds/ ha. Behera *et al*. (1997) in Western Orissa reported an yield advantage of 82 and 64 percent due to dibbling and behind plough sowing over broadcasting, respectively. Saha *et al*. (1999) opined that higher yield in behind plough sowing was due to significant increase in panicles per m^2, filled grains per panicle and test weight. The resource poor farmers in Balasore and Mayurbhanj districts of Orissa incurred less expenditure on seeding and weeding in sowing behind plough (Rs. 675/ ha) than that on broadcasting (Rs. 1840/

ha)with an yield advantage of 67 per cent (Singh *et al*., 1999). Nayak (2001) and Khatua (2002) from Bhubaneswar reported higher yield and yield attributes, better root growth and moisture extraction from deeper layers as well as more uptake of plant nutrients by line or behind plough sown crops than those sown broadcast.

6. Seed hardening

Low cost techniques like seed hardening or seed priming for combating occasional moisture stress requires urgent attention (Pathak *et al*., 1999). When the dry seeds are soaked in water or chemical solution, the quiescent cells are hydrated and the germination initiated. On shade drying before sowing the triggered germination is halted. The physiological pre-conditioning via, imbibition-drying-reimbibiton upon sowing makes up the plants in a sort of preparedeness to resist the adverse weather conditions, if any (Dawson, 1965; Thakuria and Choudhary, 1995).

Earlier studies revealed that drought tolerance can be induced by seed hardening with potassium salt (Chinoy *et al*., 1970). Studies conducted at Assam Agricultural University showed that among K salt, KCl was better for seed treatment as compared to K_2SO_4, KNO_3, K_2HPO_4 (Borgohain, 1988). Results of experiments conducted showed that seed hardening with 4 per cent KCl salt alone or together with higher K fertiliser application (60Kg K_2O/ha) and spraying of 50 ppm paraquat as anti- transpirant at tillering stage of direct seeded upland rice increased number of effective tillers and root volume, improved water economy, water use efficiency and yield and could give the crop protection against drought (Thakuria and Choudhry, 1995; Thakuria and Sarma, 1995; Pathak *et al*., 1999; Nayak, 2001; Pathak and Choudhry, 2001; Khatua, 2002).

Treating seeds with FYM slurry@ 25 kg/ha improved the yield and yield attributing characters of upland rice over non-treated seeds(Dinesh Chandra *et al*., 1991). Seed treatment with 1 per cent Ca Cl_2 solution resulted in beneficial effects on crop establishment and survival under drought (Ananda *et al*., 2002). Pre treatment of seeds with 385 ppm (10^{-3} M) sodium phosphate solution (NO_2 HP O_4) for 12-14 hours helped germination and uniformity in seedling growth even under moisture stress condition at initial stages. Grain yield increased to 2.5 t/ha with seed treatment from 2.3 t/ha without it (Singh and Chatterjee, 1980). Later, they (Singh and Chatterjee, 1981)also reported that crop established through seeds treated with water (48 hours soaking), Na_2 HP O_4, $Al(NO_3)_2$, NaCl and Co $(NO_3)_2$ solution produced 13vto 26 percent higher grain yield over non treated seeds. Dadlani *et al*. (1992) reported that emergence of eight upland cultivars was faster and the seedling growth was more due to seed treatment with aqueous sodium alginate (50 g/l) than without it. Treated seeds also absorbed 12 per cent more moisture and exhibited higher level of viability and vigour than non treated seeds.

7. Split application of nitrogen and potassium

Most of the upland rice soils in India are deficient or marginally sufficient in nitrogen content which is the main bottleneck in increasing and stabilising their yield (Mishra *et al*., 1995). But upland rice farmers seldom use fertilisers because the crop quite often fails due to uncertainty of rain. Moreover, Jana and De Datta (1971) reported that upland rice crop fertilised with 100 kg N/ha wilted temporarily at noon even at field capacity, whereas those without N did not. Under moisture stress condition the crop fertilised with 120 kg N/ha showed lower leaf water potential as compared to no N (Aragon and De Datta. 1982).

But split application of fertiliser N to supply a reasonable amount of nutrient as per demand of the crop at critical physiological stages of growth is known to improve its use efficiency. Nitrogen application in splits also helped the crop to sustain yield in weather aberrations and tide over moisture stress better (Nair *et al*. 1973). Application of half N as basal or at seedling stage and remaining half in two equal splits at tillering and panicle initiation was better than application in a single dose (Nair *et al*. 1973; Mahapatra and Srivastava, 1983; Mishra, 1992; Moorthy and Mitra, 1992; Rathi and Sharma, 1996). Nitrogen should not be applied as basal or only small quantity should be applied due to the poor nutrient holding capacity of upland soils, erratic rainfall, few roots at early growth, seed reserve for about 15 days and higher weed infestation (Patnaik and Nanda, 1965; Mahapatra and Srivastava, 1983; Maurya and Vaish,1984; Lal, 1986; Rathi and Sharma, 1996). Mishra *et al*. (1995) reported that 50 per cent N may be applied basally if there is adequate soil moisture and proper weed control from the beginning. Otherwise first split of N should be topdressed any time within three weeks after sowing following weeding. As volatilization losses are more when N is topdressed on dry soil (Gupta and O'Toole, 1986) foliar application of N should be preferred if drought occurs during tillering to panicle inititation stage (Mishra, 1992).

Singh *et al*. (1982) reported varietal differences in response to time of N application. Dwarf variety Bala yielded higher when N was applied in a single dose than in 2-3 splits, but tall traditional Brown Gora did not show marked differences when N was applied either once basally or in splits.But Kebede (2000) reported that both dwarf (ZHU XI-26) and semi tall (Kalinga III) upland rice varieties responded equally well to application of N either in two or three splits in loamy sand soil at Bhubaneswar. At CRRI, Cuttack, Orissa it was concluded that two third N should be applied at seeding and remaining one third after weeding within three weeks of germination for varieties maturing in 85-100 days.But for extra-early varieties (65-75 days) fertiliser N must be applied once either at seeding or within two weeks after germination.

Role of potassium on osmo regulation is well established. Experimental evidences from diverse crops also suggest beneficial effects of its application under soil moisture stress. Entire quantity of K-fertilisers is usually applied to soil as basal. But application of potassium in 2 to 3 splits is superior to single basal dressing in highly weathered and light textured soils containing kaolinite and illite clay minerals and in regions of high rainfall (Das and Zaidi, 2002). Application of potassium at both pre dawn and mid day time increased flag leaf water potential of wheat under different levels of stress. High level of K also decreased the loss of soil moisture through transpiration (Mishra, 2003).

Conclsion

The crop should be sown in optimum time as that sown too early usually encounters with initial stress, whereas delayed sown one suffers much from terminal drought(Behera *et al*., 1997; Mohapatra *et al*., 1997). Varieties having good seedling vigour, better rooting ability, high tissue water potential, photosynthetic rate and translocation of reserve carbohydrates to sink during stress can be well adapted during drought conditions. Sowing in lines either with seed drill, behind plough or dibbling is preferred to ordinary broadcasting in order to economise on seed rate, to facilitate inter cultivation for weed control and to obtain higher yield. Deeper placement of seeds in line also resulted in uniform plant stand and better drought tolerance than broadcasting (Dinesh Chandra *et al*., 1991). Pre conditioning of seeds empowered the rice plant to resist the moisture stress due to maintenance of higher relative water content, greater deposition of cuticular wax, better seedling vigour and root growth and greater moisture absorption (Thakuria and Choudhary; 1995, Dadlani, 1992). Moisture deficit in upland conditions prevents rice plant from making full use of applied nitrogen, therefore nitrogen is to be applied in split doses to sustain yield in moisture stress condition.

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