Environmental Management Strategies for Improving Productivity of Drought-Resistant Upland Rice

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ABSTRACT

The objective of this study was to increase growth and yield of local upland rice tolerant to drought in sub-optimal environments through the application of N, P, K and organic fertilizers. The experimental design used was split plot with three replications. The main plot was four levels of fertilizers (P), i.e. P0 (control = without fertilizer), P1 (inorganic fertilizer = N, P, K), P2 (NPK + *C. odorata* bokashi, 10 t ha^{-1}) and P3 (NPK + manure, 10 t ha^{-1} (P2), while the sub-plot was 5 indigenous tolerant-to-drought upland rice cultivars (G), i.e. Pae Tinangge (G1), Pae Indalibana (G2), Pae Bou (G3), Pae Lapodidi (G4) and Pae Waburi-Buri (G5). The results showed that manipulating plant growing conditions with NPK and organic fertilizers increased growth and yield of Pae Tinagge, Indalibana, Bou, Lapodidi and Waburi-Buri. The upland rice *cv.* Pae Tinangge showed shorter plant heights and harvest times (129 days vs 139-143 days), but produced more productive tillers and higher grain weight than the other cultivars.

Keywords: *drought stress, growing environment, local upland rice, fertilizer*. .

I. INTRODUCTION

Rice cultivation has been facing the unpredicted climate change resulting in farms left uncultivated although they are potential for rice cultivation if managed properly. The use of marginal soils virtually has to use environmental-friendly agricultural techniques by combining the application of adaptive plant varieties and optimizing farming techniques such as the utilization of organic matters to improve soil fertility and to maintain soil moisture (Surmaini *et al*., 2011).

In Southeast Sulawesi, there are several species of indigenous upland rice continuously planted in newly cleared lands, in or near forest areas via a system called *shifting cultivation*. Their productivity could reach 1.0-1.5 t ha^{-1}. This ancient method of farming is no longer applicable for nearby-forest areas, which is worsened by the unpredictable climate change. This condition causes the crops often experience drought stress which leads to a harvest failure. On the other hand, the cultivation of the indigenous upland rice plants has the potential for support our national rice supply, in addition to having quality superiority due to their nutrition and β-carotene/antioxidant contents compared to lowland rice or other commercial upland rice crops.

Previous studies on several upland rice cultivars conducted both in the laboratory and in a plastic house, which simulated dry land conditions with certain levels of drought stress suggested that several indigenous upland rice cultivars highly tolerant to drought were cultivar Pae Wapantoga, Waburi-buri, Lapodidi, Nggalaru, Biu, Bou, Momea, and Tinangge (La Ode Afa and Anas, unpublished).These cultivars still need to be tested in *in-situ* conditions to obtain cultivars that could produce high yields in either optimal or sub-optimal growing conditions (Altman, 2003).

The objectives of the present study were to increase the productivity of indigenous upland rice cultivars tolerant to drought stress through the applications of NPK and organic fertilizers, and to identify cultivars that could produce high yields in either optimal or sub-optimal growing conditions.

II. MATERIALS AND METHODS

The experiment was conducted on Halu Oleo University’s Agricultural Faculty’s experimental field from April to August 2015. The grain filling stage of the crop was during the Indonesian dry season (Figure 1).

Five upland rice cultivars were tested, i.e. Pae Tinangge, Indalibana, and Bou indigenous to the Regency of Konawe Selatan, Pae Lapodidi indigenous to the Regency of Muna, and Pae Waburi-buri indigenous to the Regency of Buton Utara. The experiment was carried out according to the split plot design with three replications. The main plot was four levels of fertilizers (P), i.e. P0 (control = without fertilizer), P1 (inorganic fertilizer = N, P, K), P2 (NPK + *C.*

odorata bokashi, 10 t ha^{-1}) and P3 (NPK + manure, 10 t ha^{-1} (P2), while the sub-plot was 5 indigenous upland rice cultivars tolerant to drought (G), i.e. Pae Tinangge (G1), Pae Indalibana (G2), Pae Bou (G3), Pae Lapodidi (G4) and Pae Waburi-Buri (G5). Variables observed were plant height, number of productive tillers, and flowering and harvest time. Data were analyzed with ANOVA and the significant differences between treatment means were tested with the *Duncan's Multiple Range Test* (DMRT) using SAS 9.1.

III. RESULTS AND DISCUSSION

The intensities of rain falls during the study are presented in Fig 1. ANOVA suggests that there were interaction effects among fertilizer and cultivar treatments on flowering and harvest time. This indicates that there were different responses among cultivars because of fertilizer treatments (Fig 2 and 3). No interaction effects were observed on plant heights, number of productive tillers, and grain weight per hill. The fertilizer and indigenous upland rice cultivar treatments were found to show simple effects on observed variables (Table 1).

The five indigenous upland rice cultivars grown at four combinations of fertilizer application (without fertilizer, NPK fertilizers, NPK + *C. odorata* bokashi, and NPK + manure) showed insignificantly different flowering time. However, the application of fertilizers resulted in a significant different flowering time compared to control (without fertilizer application). The fertilizer applications caused all the five tested cultivars to flower earlier than those without fertilizer application (Fig 2). Plants that flower earlier generally possess a better adaptation to drought by shortening their grain maturing periods (Lafitte *et al.*, 2006).

The harvest time of the 5 cultivars studied under the 4 levels of fertilizer applications were found to be significantly different (Fig 3). The different plant growing conditions caused plants to complete their life cycle differently (Yoshida, 1981). Upland rice *cv*. Pae Tinangge showed the shortest harvest time of the five tested cultivars, followed by cultivar Pae Waburi-Buri, Bou, Indalibana, and Lapodidi. In addition to the effect of organic fertilizers, drought stress taking place during the grain filling stage (Fig 1) was most likely one of the factors influencing the different harvest time among the tested upland rice cultivars, especially in cultivar Pae Tinangge. The shortest harvest time found in this cultivar was presumably brought about by the ability of this cultivar to develop a strategy in order for it to be able to avoid the drought stress before experiencing a more severe drought stress. One of the plant strategies to avoid drought stress is plant rapid phenological development (i.e. earlier flowering and grain maturing) and remobilization of pre-anthesis assimilate (Mitra, 2001) but their grain production relatively remains high. Kumar *et al.* (2009) suggested that under severe dry conditions, tolerant cultivars flower ± 8 days earlier compared to susceptible ones. Samaullah and Darajat (2001) reported that genotypes that can flower earlier and produce less empty grains under a drought stress possess drought tolerant traits. When their flowering time comes late, genotypes under drought stress will shorten their grain filling stage, which in turn will negatively affect their yield. Kumar *et al.* (2007); Laode Afa *et al.* (2013) suggested that tolerant lines possess the ability to maintain their high biomass production and harvest index when exposed to dry soils. Pantuwan *et al.* (2002) stated that *drought escape* mechanisms of the short-living genotypes exposed to a long drought stress are probably derived from the contribution of pre-anthesis assimilate as an assimilate source during their grain filling stage. The different yield potential found on cultivar Pae Tinangge compared to the other tested cultivars was probably brought about by the difference in pre-athesis assimilate contribution to the grain production. *Drought escape* is a strategy very effective in reducing negative effects of drought stress through adapting water availability to the plant phenology (Mitchell *et al.*, 1998).

The indigenous upland rice cv. Tinangge produced the highest rice grain weight among the 5 cultivars studied (Table 1). Moreover, cultivar Pae Tinangge also showed more productive tillers and shorter plant heights compared to the other cultivars. Plant height is closely related to lodging (Peng *et al.*, 2008). One of plant characteristics tolerant to lodging is having a plant height of 115 – 120 cm (Ma *et al.*, 2006), and cultivar Pae Tinangge is the closest of the five cultivars to such a characteristic.

Compared to control (without fertilizer application), the application of fertilizers resulted in significantly different plant heights, number of productive tillers, and grain weights per hill. Fertilizer application, either with NPK only or with NPK plus organic matters (*C. odorata* bokashi or manure) showed better plant heights, number of productive tillers, and grain weights per hill compared to control. The application of fertilizer NPK + *C. odorata* bokashi resulted in the highest grain weight per hill (Table 1). Organic fertilizers can improve soil physics, chemistry, and biology. The most important aspect of the organic fertilizer is N supply to the soil. microbial biomass having a shorter cycle, the organic phase acts as a biocatalyst to supply mineral nutrients and for the nutrient pool per se (Reichardt *et al.*, 2003). Other benefit of organic matters is a change in microclimate and a reduction in soil temperature fluctuations (Sharratt, 2002). Addition of organic matters can improve soil stability, macro pores, and infiltration rate. Organic matters can supply nutrients, increase N absorption efficiency and thus reducing N loss due to leaching, and increase plant productivity (Cherr *et al.*, 2006).

IV. CONCLUSSIONS

Manipulating plant growing conditions with NPK and organic fertilizers increased growth and yield of upland rice *cv*. Pae Tinagge, Indalibana, Bou, Lapodidi and Waburi-Buri. The upland rice *cv.* Pae Tinangge showed shorter plant heights and earlier harvest times (129 days vs 139-143 days), but produced more productive tillers and higher grain weights than the other cultivars.

V. ACKNOWLEDGMENT

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APENDICES

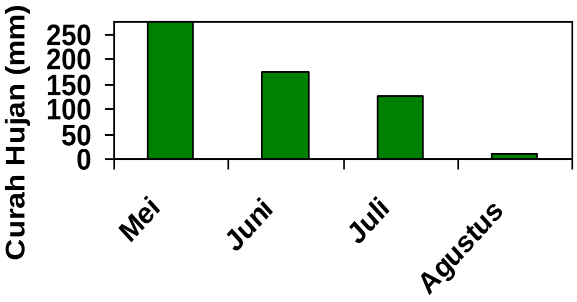

Fig 1. Rain falls (mm) during the study

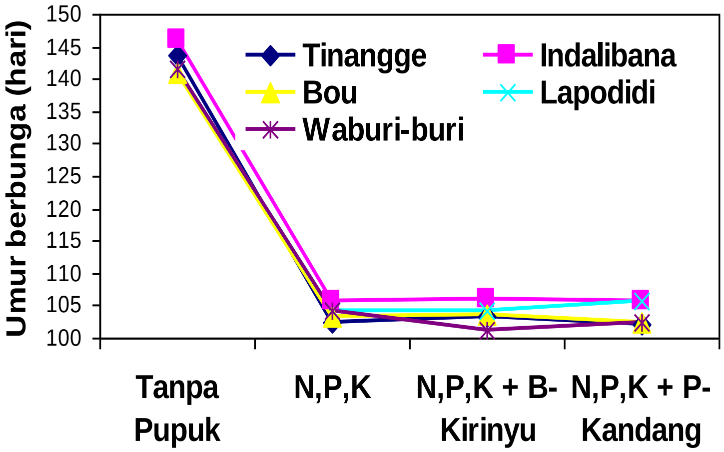

Fig 2. Interaction effect of fertilizer applications and indigenous upland rice cultivars on plant flowering time

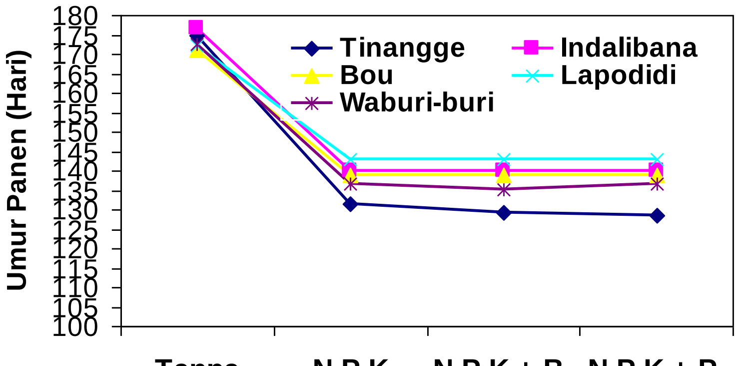

Fig 3. Interaction effect of fertilizer applications and indigenous upland rice cultivars on harvest time

Table 1. Simple effect of fertilizer applications and indigenous upland rice cultivars on plant heights, number of productive tillers, and grain weights

Treatments	Variables		
	Plant heights (cm)	Productive tiller numbers	Grain weight per hill (g)
I. Fertilizer			
1. Without fertilizer	111.5c	2.8b	29.9c
2. N, P, K	147.9a	11.3a	116.4ab
3. N, P, K + *C. odorata* Bokasih	146.3a	10.95a	131.8a
4. N, P, K + manure	139.4b	11.5a	106.2b
II. Indigenous upland rice cultivars			
1. Pae Tinangge	131.7bc	9.9a	127.9a
2. Pae Indalibana	136.9abc	9.5ab	104.1ab
3. Pae Bou	144.4a	8.4bc	87.8bc
4. Pae Lapodidi	129.6c	9.7a	69.0c
5. Pae Waburi-buri	138.8ab	8.2c	91.5bc

Note: Values in the same column followed by the same letter indicate insignificant differences according to DMRT at $\alpha = 0.05$.