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Yield Evaluation of Upland Rice Varieties *(Oryza sativa L.)* in Several Levels of Soil Water Content

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Abstract. Production and productivity of upland rice is still very low due to limited water in the upland rice ecosystem. The objective of this study was to evaluate the yields of upland rice varieties at several levels of soil water content. The experiment was conducted at the Growth Centre LLDIKTI Wilayah I Medan from March to July 2013. This research used a factorial randomized block design with two factors and replicated three times. Five upland rice varieties as the first factor, namely Batutegi, Inpago 4, Limboto, Situbagendit, and Situpatenggang. Second factor was four levels of soil water content, namely: 80% of field capacity (FC), 60% of FC, 40% of FC, 20% of FC. The main effect of upland rice varieties and soil water content significantly affected ($p<0.05$) the productive tiller number, percentage of empty and filled grain, the panicle length, 1000 grain weight, and weight grain per clumps. The interaction effect between upland rice varieties and soil water content showed significant interaction on the panicle length, 1000 grain weight, and weight grain per clumps. Situpatenggang variety showed the best yield characters like productive tiller number, percentage of empty and filled grain than the other four varieties. Combination treatment of Situpatenggang variety with 80% FC showed the highest panicle, 1000 grain weight, and weight grain per clumps. The smallest percentage decreased in grain yield per clumps due to decreased the level of soil water content was found in the Inpago 4 variety, so it can be recommended to plant Inpago 4 on soil which had low level of soil water content.
Keywords: upland rice; yield; soil water content; varieties

INTRODUCTION

China, India and Indonesia are the three main rice producer countries which produce about 60% of rice world production (FAO, 2013). Based on FAOSTAT, world rice production and area in 2010 were about 700 million tons and 60 million hectares, where about 90% was produced in Asia and 3.7% in Africa. Rice ecosystem in worldwide is divided to irrigated rice 75%, rainfed rice 20% and upland rice 4% (FAO, 2013).

The contribution of upland rice production to national rice needs is still low only 5.3% or 3.744 million tons. Upland rice cultivation area and productivity respectively 1.129 million ha and 3.3 ton.ha^{-1} (Kementan RI, 2015). One of the main problems in increasing the productivity of upland rice is that the water source for cultivation only depends on rainfall and its distribution is often anormal (Toha, 2013). Limited water in dry land causes upland rice cultivation can be very risky to experiencing drought stress.

Drought is the main abiotic stress that affects 20% of the total rice in Asia (Pandey and Bhandari, 2008). Effect of drought stress on plants according to Farooq *et al*., (2009) include (1) the decline of plant growth and production (Zhang *et al*., 2004, Wu *et al.*, 2008), (2) the relative water content (Siddique *et al*., 2001), (3) nutrient absorption, (4) photosynthetic rate (Lanna and Vianello, 2021), (5) assimilate partition (Lepot *et al.*, 2006), however the stress can (6) increase respiration rate (Liu *et al.*, 2004) and (7) reactive oxygen species (ROS) (Sairam *et al.*, 2005).

Effect of drought stress on upland rice include decreased in growth and development (Tripathy *et al*., 2000; Manikavelu *et al*., 2006), decreased in root length and root dry matter (Mayly *et al*., 2015), decreased plant height (Sarvestani *et al*., 2008), decreased in the number of tillers (Bunnag and Pongthai, 2013, Mostajeran dan Eichi,2009), reduced 1000 grain weight (Mostajeran dan Eichi. 2009; Venuprasad *et al*. 2007 dan Castillo *et al*. 2006), decreased in yield of upland rice (Heinermann *et al*., 2007).

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The objective of this study was to evaluate the yields of upland rice varieties at several levels of soil water content.

METHODS

Description of the Experimental Site

The greenhouse experiment was performed at Growth Centre LLDIKTI Region I in Peratun Street Medan, Sumatera Utara from March to July 2013. Geographically, the experimental site is located at 3° 36'42.3" North latitude and 98° 42'49.1" East longitude with an altitude of 25 meters above sea level. Meteorological data during the cultivation period showed the relative humidity of 62.17%, potential evapotranspiration of 988.03 mm with an average minimum and maximum temperature of 27°C and 38.60°C, respectively. Result of soil analysis were soil textural class was silty loam, C-Organic 1.37%, N-Total 0.17%, P-Available (Bray II) 17.18 ppm, Exchangeable K 0.14 me/100g, Mg 1.28 me/100 g, Na 0.13 me/100 g, Cation Exchange Capacity (CEC) 17.31 me/100 g, pH (H_2O) 6.23.

Plant Materials.

Varieties of five upland rice namely Batutegi, Inpago 4, Limboto, Situbagendit, and Situpatenggang, were collected from Indonesian Rice Research Center Sukamandi, West Java, Indonesia.

Design and Experimental Procedure

This research used a factorial randomized completely block design with two factors and replicated three times. First factor was upland rice varieties with 5 treatments, namely Batutegi, Inpago 4, Limboto, Situbagendit, and Situpatenggang. Second factor was soil water content with 4 treatments, namely: 80% of field capacity (FC), 60% of FC, 40% of FC, 20% of FC. Seedlings were planted in a polybag size of 10 kg soil, and then polybag were covered with plastic to prevent water escaping from the polybag. Each polybags were planted 5 seeds, and then 2 weeks after planting (wap) we reduced them to two plants per polybag. Fertilizers dosage were 70 kg $N.ha^{-1}$, 2.5 Kg $P_2O_5.ha^{-1}$ and 30 Kg $K_2O.ha^{-1}$. Urea fertilizer was given three times, namely 1/6 doses at 2 wap, 3/6 doses at 6 wap, 2/6 doses at flower primordia phase. SP36 dan KCl fertilizers were given at 2 wap. Pest and disease control were carried out according to the symptoms that occur in the fields. Watering was carried out daily and soil water content treatments were started at 14 days after planting and ended at harvest.

Data Collection and Measurements

Measurement of upland rice yield data were collected at harvest time. Productive tillers number was counted by counting the number of tillers that produce spikes and seed. Percentage of empty and filled grains were counted by comparing the number of empty or filled grains with the total number of grains. Panicle length was measured as the length from panicle tip to the panicle neck of the main panicle. 1000 grain weight was measured by weighing the random of 1000 grains at 14% water content. Weight grain per clumps was measured by weighing all the grains per polybag.

Data Analysis

Data were analyzed by using factorial analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) and advance test by using Duncan Multiple Range Test at 5% significance level

RESULTS AND DISCUSSION

The results of Anova showed significant interaction effect ($p<0.05$) on the panicle length, 1000 grain weight, and weight grain per clumps but there were no significant interaction effect on the productive tiller number, percentage of empty and filled grain. The main effect of upland rice varieties and soil water content each had a significant effect on all these yield parameters. The interaction effect of upland rice varieties with soil water content on panicle length, 1000 grain weight, grain weight per clumps can be seen in Figure 1.

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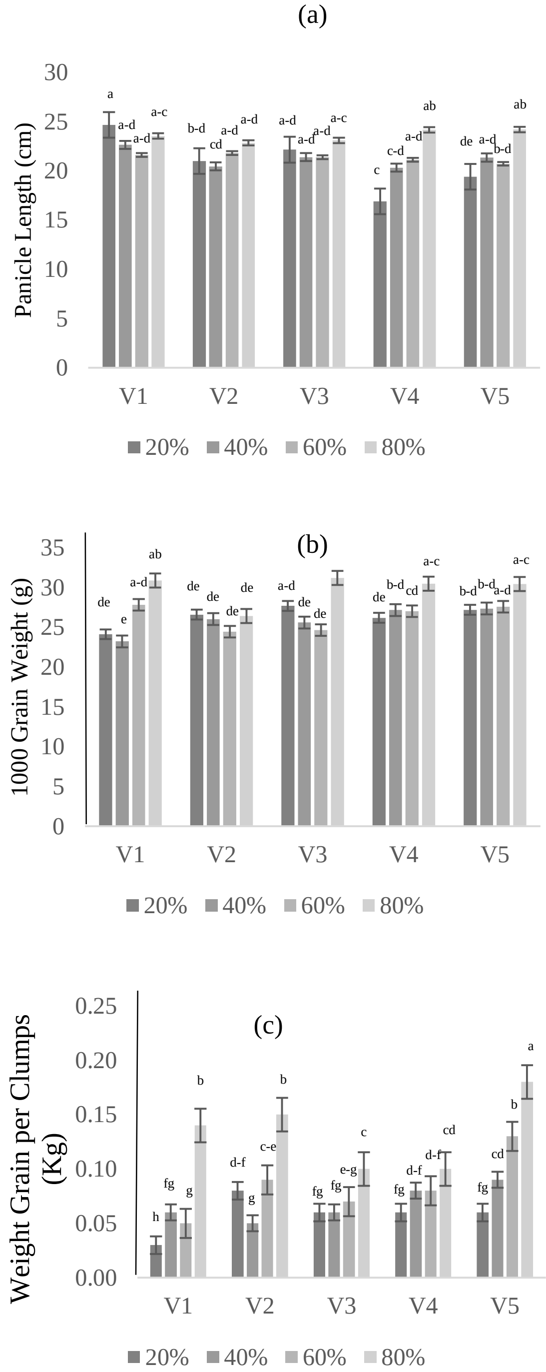

Figure 1. Interaction Effect of Upland Rice Varieties and Soil Water Content on (a). Panicle Length, (b). 1000 Grain Weight, (c). Weight Grain per clumps. Means are plotted ±1 SE. Statistical comparisons between Upland Rice Varieties treatments and Soil Water Content treatment are based on Duncan Multiple Range Test ($p<0.05$). Upland rice varieties Treatment included V_1= Batutegi, V_2 = Inpago 4, V_3= Limboto, V_4= Situbagendit, V_5= Situpatenggang. Soil Water Content Treatment included K_1= 20% FC, K_2 = 40% FC, K_3 = 60% FC, K_4= 80% FC.

In general, the combination of upland rice varieties with 80% FC showed the higher value in panicle length, 1000 grain weight, weight of grain per clumps compared to the combination of varieties with the other three soil water content. The panicle length parameter at combination of upland rice Batutegi, Inpago 4, and Limboto varieties with 20% and 80% FC showed no significant difference, while the combination of Situbagendit and Situpatenggang varieties with 20% FC showed a significant difference

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with the combination each varieties with 80% FC. Soil water content reduction caused decrease of panicle length except on Batutegi variety, which on 20% FC, panicle length increased by 4.8%. Panicle length decreased on 20% FC occurred on Inpago 4, Limboto, Situbagendit, Situpatenggang varieties respectively by 8%, 4%, 30.1%, 19.8%. Soil water content reduction caused drought stress on plants that can limit rice growth and yield. According to Lanna and Vianello (2021), upland rice plants reacted to drought stress by slowing down their growth.

Combination of Limboto with 80% FC showed the highest 1000 grain weight which showed no significant difference with combination Batutegi, Situbagendit and Situpatenggang with 80% FC, also no significant difference with the combination Batutegi and Situpatenggang with 60% FC, and combination Limboto with 20% FC. Soil water content reduction caused reduction of 1000 grain weight, which differs between varieties depending on the ability of the variety to tolerate drought. According to Shafeek *et al.,* (2006) and Farooq *et al*. (2009), the mechanism of drought tolerance in each genotype is influenced by gene action.

The highest weight grain per clumps was found in the combination of Situpatenggang with 80% FC which showed the significant difference with all other treatment combinations. Soil water content reduction caused reduction on weight grain per clumps, when it was compared with combination treatment of Situpatenggang variety with 80% FC, then weight grain per clumps in 20% FC decreased respectively on Batutegi (83.3%), Inpago 4 (55.6%), Limboto, Situbagendit, and Situpatenggang (66.7%). It is suspected that Inpago 4 had a higher tolerance to cope drought stress than the other four varieties. According to Mayly *et al*., (2015) that Inpago 4 showed the highest root length and heaviest root dry matter at 20 and 40% FC at the early test. According to Heinemann *et al.,* (2015)**,** due to drought-stress conditions, rice yield in upland cultivation (especially tropical areas) decreased by up to 35 %. Screening of root traits under drought stress conditions can be used to increase crop yield under these conditions (Comas *et al*., 2013).

The main effect of upland rice varieties treatments on the productive tiller number, percentage of empty and filled grain can be seen in Figure 2. The maximum productive tiller number of upland rice was found on Situbagendit, which was statistically different from four other varieties. The second highest were Situpatenggang which was statistically different from Batutegi but not statistically different from Limboto, and Inpago 4. And the lowest productive tiller number of upland rice was found on Batutegi. The lowest percentage of empty grain was found on Situpatenggang which was statistically different from Situbagendit but not statistically different from three other varieties. And the highest percentage of empty grain was found in Situbagendit. The highest percentage of filled grain was found on Situpatenggang which was statistically different from Situbagendit but not statistically different from three other varieties. And the lowest percentage of filled grain was found in Situbagendit. Situpatenggang varieties showed the good yield characters than the other four varieties. It was suspected that the genotypes of these varieties were superior in drought stress condition, where phenotypes were influenced by genotypes and environment factors. Differences in grain yields under drought stress condition caused by genotypes were also shown by Guimarães *et al.,* (2013) and Lafitte *et al*., (2007)

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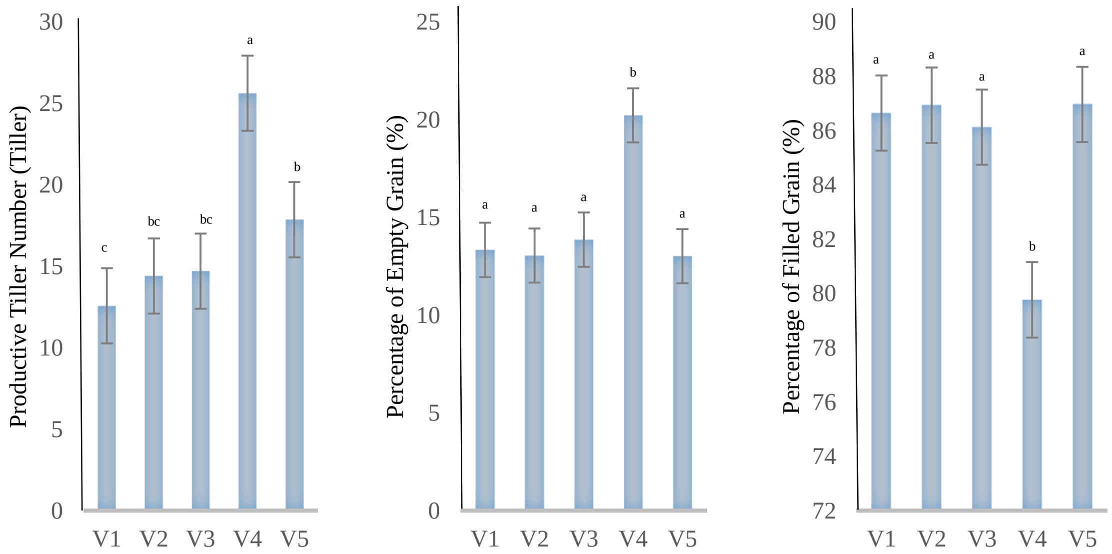

Figure 2. Productive Tiller Number, Percentage of Empty and Filled Grain in Different Upland Rice Varieties. Means are plotted ±1 SE. Statistical comparisons between Treatment Levels of Upland Rice Varieties are based on the Duncan Multiple Range Test ($p<0.05$). Upland rice varieties included V_1= Batutegi, V_2 = Inpago 4, V_3 = Limboto, V_4= Situbagendit, V_5= Situpatenggang.

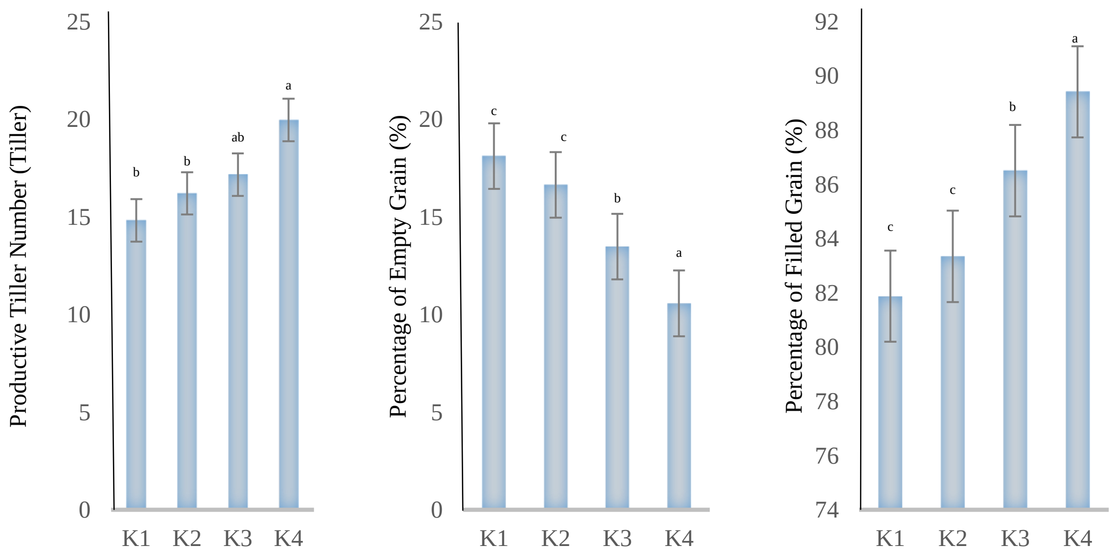

Figure 3. Productive Tillers Number, Percentage of Empty and Filled Grain in Different Levels of Soil Water Content. Means are plotted ±1 SE. Statistical comparisons between Treatment Levels of Soil Water Content are based on Duncan Multiple Range Test ($p<0.05$). Soil Water Content included K_1= 20% FC, K_2 = 40% FC, K_3 = 60% FC, K_4= 80% FC.

The main effect of soil water content treatments on the productive tiller number, percentage of empty and filled grain can be seen in Figure 3. The maximum productive tiller number from soil water content treatment was found at 80% FC, which was not statistically different from 60% FC but statistically different from 40 and 20% FC. And the lowest productive tiller number was found on 20% FC. The lowest percentage of empty grain was found at 80 % FC which was statistically different from three other soil water content. The highest percentage of empty grain was found at 60% FC. The highest percentage of filled grain was found at 80% FC which was statistically different from three other soil water content. And the lowest percentage of filled grain was found

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on 20% FC. Reduction of soil water content of fields capacity significantly decreased the yield of upland rice. It can be seen that upland rice yields at 20%, 40%, and 60% FC were lower than upland rice yields at 80% FC. It was suspected that in the generative phase more water is needed to fill the seeds, so that the lack of water in this phase results in a decrease in yield and production of upland rice. Drought contributed to upland yield reduction, low grain yield, low 100 grain mass, low number of filled grain, high number of empty grain, and high spikelet sterility (Lanna and Vianello, 2021).

CONCLUSION

Based on yield evaluation, Situpatenggang variety showed the best yield characteristics, namely productive tiller number, percentage of empty and filled grain, than the other four varieties. Among the tested treatments, combination Situpatenggang variety with 80% FC showed the highest panicle length, 1000 grain weight, and weight grain per clumps. Inpago 4 variety showed the smallest percentage decrease in grain yield per clumps due to decreased the level of soil water content.

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