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Research Article

Alteration agronomic traits performance of sweet potato cultivars from drylands to paddy fields

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Abstract: This study aimed to evaluate changes in agronomic performances of some sweet potato cultivars planted in the rain-fed dry land and paddy fields. Completely randomized block design with three replications on a single factor of 12 sweet potato cultivars was done in two locations. The first location is the rain-fed dry land that formerly planted corn; located in Jatikerto, Kromengan District, and second is an irrigated paddy field that previously planted with rice, located in Wringinsongo, Tumpang District, Malang Regency. All cultivars that planted in both locations were applied to packaged standard cultivation technology for sweet potato. The parameters observed were storage root weight and vines weight (kg/plant), storage root yields and vines yield (t/ha), harvest index (%) and root/shoot ratio to describe the efficiency level of dry matter translocation to storage root. The results showed that there was a change of agronomic performance in sweet potato cultivars that planted between on the dry land and paddy fields, especially for storage root weight, storage root yield (t/ha) and root/shoot ratio. Changes in the sweet potato cultivation in the dry land to paddy fields are shown by an increase in storage root yields ranging from 2-4 times or reach 206 - 417%.

Keywords: *dry land, harvest index, paddy fields, root/shoot ratio, sweet potato*

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Introduction

Paddy fields and dry land are two types of agroecosystems that are different from each other. Paddy fields are usually based on the main commodities of rice, on the contrary of dry land are distinguished between the main crops of legumes and tuber crops, vegetables, and estate crops (Susilowati, 2015). Paddy fields and dry land have different soil morphological, physical and chemical properties, including their classification (Rahayu et al., 2014).

According to the research of Rahayu et al. (2014), the differences were seen in the morphology of paddy fields and dry land are in the arrangement of humidity, colour, and plough shape on the soil profile. In soil physical properties between the two types of wetland and dryland agroecosystem, there are differences in soil structure, bulk density and soil consistency. In the chemical properties of the soil, the difference lies in the cation exchange capacity (CEC), the content of K^+, Na^+, Ca^{2+} and Mg^{2+}, C-organic and base saturation, on higher in paddy fields compared to dry land. The differences in soil classification in both types of agro-ecosystem occur in sub-orders, as a result of changes in soil moisture regimes. The moisture regime in the cultivation process on rice fields is created through a flooding process, where according to Moormann and van Breemen (1986) through this inundation process a reduction state can be created which can change the morphological and physical-chemical characteristics of the original soil profile. It was also explained that the soil treatment process in a way that was flooded and the soil structure was destroyed (paralyzed) before rice cultivation could change the physical and chemical properties of the soil. The high C-organic value in the paddy soil comes from the addition of organic matter from the remaining roots of rice plants and the decomposition process of organic material which is slower in anaerobic conditions, can preserve organic matter in the soil (Rahayu et al., 2014). Rice fields also have a high level of biodiversity compared to dry land (Puspita et al., 2005).

Sweet potato is a plant that is easy to adapt to the conditions of various agroecosystems, although the response of these plants generally varies when cultivated in different agroecosystems, due to the interaction between genotypes and the environment (Nafi'ah et al., 2017). Sweet potato yield and yield components that are cultivated on wetlands are better than on dry land (Nafi'ah et al., 2016). Therefore, this study aimed to evaluate the changes in agronomic performance of sweet potato cultivars grown on dry land and in paddy fields after rice.

Materials and Methods

Experimental site

This research was carried out in two locations, first on dry land located in Jatikerto Village, Kromengan District, Malang Regency, previously planted with corn; second on rice fields after rice plants, located in Wringinsongo, Tumpang District, Malang Regency. The first location is at an altitude of $\pm$ 350 m above sea level with Inceptisol soil type and the second location is at an altitude of $\pm$ 600 m above sea level with Vertisol. The soil properties (physical and chemical soil) of the two locations are presented in Table 1. Research in the first location took place from February to June 2017 and at the second location took place from May to September 2017. Climatic conditions represented by the distribution of rainy days and rainfall volume during the study from the two locations are presented in Table 2.

Research materials

The plant material used in this study consisted of 12 cultivars, namely: BIS OP-61-OP-22, BIS OP61-OP-37; BIS OP61-♂-8; BIS OP61-♂13; BIS OP61-OP-23; and Beta 2-♀-29. Besides the six clones, several cultivars were also cultivated, namely BIS OP-61, Papua Solossa, Beta 2, Cangkuang, Jago and 73-6 / 2 as the cultivar control.

Experimental design and treatment

The single-factor of trial design, namely sweet potato cultivars, was planted in a completely randomized block design with three replications applied in the two locations. Each clone planted in a plot measuring 3 m x 5 m, consisting of 4 rows with a spacing of 25 cm in rows, so that in each plot consists of 48 cuttings. All experimental plots were given basic fertilizer of NPK Phonska (15% N, 15% P_2O_5, 15% K_2O) at a dosage of 300 kg/ha and applied twice, firstly 1/3 of the portion was given at plant age one week after planting, and the rest was given at plant age 1.5 months.

Standard cultivation technology for sweet potato was applied. Weeding, down and up riding activities are standard activities in sweet potato cultivation, with the aim of suppressing weed growth, reducing the number of unexpected storage roots in addition to the main of storage roots, soil clumping, and improving aeration for the roots. Plants in the two locations were harvested at different ages, at the first location the plants were harvested at the age of four months and the second location plants were harvested at 4.5 months of age. The harvest age at the second site is longer because the growth of the sweet potato at a higher altitude tends to be slower. The parameters observed and presented in this study only storage root weight/plant, fresh vines weight/plant, yields estimation of fresh storage root and vines, harvest index (%) and root/shoot ratio. The last two parameters (harvest index and root/shoot ratio) are intended to describe the level of efficiency of dry matter translocation from the source (foliage) to the sink (storage root).

Data analysis

Data were processed using a combined analysis method in a completely randomized block design following the procedure outlined by Gomez and Gomez (1984). Similarly, the Least Significant Differences (LSD) at 1% level of probability was used to detect differences between treatment means. Additional data in the form of physicochemical properties of the experimental site and agrometeorology data were only presented descriptively.

Results and Discussion

Differences in soil properties between dry land and paddy fields

The physical and chemical properties of soil from soil analysis (Table 1) give a general description of the differences in soil characters represented by soil texture, soil pH, organic C levels, C/N ratio, N, P, K, Ca, Mg, CEC and base saturation. Paddy fields have a higher pH, higher C-organic levels, higher N, P, Ca and Mg content, higher CEC and base saturation than dry land. The differences in the physical and chemical conditions of the soil show that the condition of soil fertility in paddy fields is higher than on dry land.

Table 1. Physico-chemical properties of the experimental site (at first location at Jatikerto, Kromengan District; ± 350 m above the sea level; and soil type Inceptisol and the second location at Wringinsongo, Tumpang District, 600 m above sea level; and Vertisol soil type) in 2017

Location	pH 1:1 H₂O	pH 1:1 KCl 1 N	C-organic (%)	N-total (%)	C/N	P-Bray 1 (mg/kg)	K (NH₄OAC 1 N pH 7)	Na (NH₄OAC 1 N pH 7)	Ca (NH₄OAC 1 N pH 7)	Mg (NH₄OAC 1 N pH 7)	CEC (NH₄OAC 1 N pH 7)	Number of bases	Base saturation	Sand (……% ……)	Silt (……% ……)	Clay (……% ……)
First Location (*Jatikerto*)	5.5	4.9	0.87	0.09	10	0.76	2.61	1.27	6.57	2.19	18.96	12.65	67	17	35	48
	Acid		Very low	Very low	Low	Very low	Very high	Very high	medium	High	Medium		High	Clay		
Second Location (*Wringinsong*)	6.30	5.50	1.29	0.14	9.00	3.74	1.70	1.30	12.40	5.27	29.21	20.68	71	20	47	33
	slightly acid		Low	Low	Low	Very low	Very high	Very high	High	High	High		Very high	Silty Clay Loam		

The analysis of soil properties from Soil science laboratory, Brawijaya University

Table 2. Distribution of rainy days and amount of rainfall of the experimental site in 2017 (at first location at Jatikerto, Kromengan District; ± 350 m above the sea level and the second location at Wringinsongo, Tumpang District, 600 m above sea level)

Location	Monthly Rainy Days during 2017 (days/month)											
	Jan	**Feb**	**March**	**April**	**May**	**Jun**	**Jul**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
First location (Jatikerto, Kromengan District, Malang)	20	13	10	12	4	3	1	0	3	8	16	16
Second location (Wringinsongo,Tumpang District, Malang)	22	11	14	16	10	3	2	0	2	5	24	21
Location	**Monthly Rainfall Volume during 2017 (mm/month)**											
	Jan	**Feb**	**March**	**April**	**May**	**Jun**	**Jul**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
First location (Jatikerto, Kromengan District, Malang)	498	274	441	446	38	67	4	0	24	94	265	258
Second location (Wringinsongo,Tumpang District, Malang)	382	99	220	341	136	22	15	0	45	52	425	281

Source: BMKG Climatology Station Malang (2018)

This was also conveyed by several previous some researchers (Nafi'ah et al., 2017; Nafi'ah et al., 2016; Rahayu et al., 2014). The amount of rainfall and the number of rainy days during the trials are presented in Table 2. Rainfall in both locations is 2049 mm/year and 2018 mm/year, and the number of rainy days is 106 days and 130 days, respectively. The research period in two locations was different in time, at the first location earlier, i.e. from February to June, and in the second location, it ran from May to October in 2017. The amount of rainfall obtained in the first location is quite beneficial, during the period of initial plant growth; rainfall is quite high, and the last two months before harvest it decreases to lower than 100 mm/month. The agro-ecosystem in the first location is rainfed dry land so that if the amount of rainfall during the first three months of plant growth is high, can enough to reduce the risk of low water availability. The low water availability becomes a limiting factor for plant growth. On the other hand, in the second location, during the trial period (May - October) there was low rainfall, but because the agroecosystem was irrigated rice fields so the low rainfall was not a limiting factor for plant growth. Differences in soil properties and rainfall significantly affect plant growth. Lestari and Hapsari (2015) indicated that the sweet potato plant was affected by excessive or very low rainfall. Likewise, according to Biswal et al. (2017) storage root development and bulking is extremely sensitive to both deficit as well as excess water. The type of sweet potato growth can change from forage type to dual-purpose or root production by the amount of rainfall in the dry land. Likewise, the results of a study conducted by Indawan et al. (2018) those changes in the soil properties can affect the yield components of sweet potato.

Changes in agronomic performance of sweet potato cultivars were evaluated in both locations

Sweet potato agronomic performance was influenced by differences in the environment or agroecosystem, differences in cultivars, and the interaction between cultivars and the environment (Table 3). The differences in agroecosystem affected the performance of storage root weight per plant and its storage root yield estimation per hectare, harvest index and root/shoot ratio, but the fresh weight of vines and estimation of vines yield is not different in the two environments.

The performance of cultivars in both locations varied in the parameters of storage root weight, storage root yield and root/shoot ratio, but for the parameters of fresh vines weight per plant, vines yield/hectare and harvest index of all cultivars have the same response, were proportionally increased or decreased by changes in soil properties and climate component (Tables 3, 4, and 5). Thus, the change in agronomics performance is only indicated by storage root weight, estimation of storage root yield and root/shoot ratio when the twelve of sweet potato cultivars are planted from rainfed dryland shifting to irrigated rice fields.

The changes of sweet potato cultivars performance especially in storage root weight per plant and storage root yield (Table 3), were caused by the translocation of dry matter to storage root are higher than to vines as it indicated by the root/shoot ratio (Table 6). The root/shoot ratio in rainfed dry land (in Location 1) ranges between 0.5 – 2.1 increased to 1.7 – 5.7 at paddy land in Location 2 (Table 6). Value of percentages increase in storage root yield is higher than its vines yield (Table 6). Biswal et al. (2017) explained that irrigation and fertility levels significantly influenced sweet potato growth, storage root and vine yields. Gajanayake and Reddy (2016) in their study on sweet potato responses to mid- and late-season soil moisture deficits showed that biomass partitioning to storage roots declined linearly and vice versa leaf and stem portioning increased with increased irrigation and Biswal et al. (2017) explained that sweet potato gives a response to nutrient (fertilizer) if the soil conditions are quite moist.

Table 3. The combined analyses of variance over two locations for the sweet potato cultivars trials

Source of variation	df	Mean Square											
		Storage root weight (kg/plant)		Fresh vines weight (kg/plant)		Harvest Index (%)		Storage root yield (t/ha)		Vines yield (t/ha)		Ratio root/shoot	
Location	1	5.859	**	0.25	ns	6666.36	**	9374.55	**	403.37	ns	75.23	**
Rep/Location	4	0.005		0.09		103.18		8.64		144.61		1.58	
Cultivar	11	0.206	**	0.06	**	379.19	**	330.03	**	100.20	**	3.90	**
Cultivar x Location	11	0.092	**	0.02	ns	73.92	ns	146.66	**	26.21	ns	1.45	**
Pooled error	44	0.003		0.01		38.88		5.02		14.54		0.40	

Remarks: ns = not significant; ** = significant at 1% level

Table 4. Performance of storage root weight and fresh vines weight per plant in both locations (location 1 = rainfed dry land and location 2 = irrigated rice fields)

No	Clone	Storage root weight (kg/plant)		Fresh vines weight (kg/plant)	
		Location 1	Location 2	Location 1	Location 2
1	BIS OP-61-OP-22	0.41	0.86	0.44	0.40
2	BIS OP-61-OP-37	0.39	1.61	0.32	0.46
3	BIS OP-61-♂-8	0.25	0.88	0.57	0.69
4	BIS OP-61-♂-13	0.32	1.00	0.29	0.30
5	BIS OP-61-OP-23	0.41	1.15	0.38	0.47
6	BETA 2-♀-29	0.44	0.90	0.38	0.45
7	BIS OP-61	0.27	0.60	0.50	0.80
8	PAPUA SOLOSSA	0.24	0.56	0.39	0.67
9	BETA 2	0.39	1.01	0.40	0.43
10	CANGKUANG	0.13	0.50	0.40	0.50
11	JAGO	0.23	0.78	0.34	0.55
12	73-6/2	0.30	0.77	0.34	0.45
	LSD (1%)	0.14	0.11	0.25	0.19

Table 5. Performance of storage root yields and fresh vines yields, as well as percentages, increase in storage root yields and vines yields in both locations (location 1 = rainfed dry land and location 2 = irrigated rice fields)

No	Clone	Storage root yield estimation (t/ha)		Percentages increase in storage root yields (%)	Vines yield estimation (t/ha)		Percentages increase in vines yield (%)
		Location 1	Location 2		Location 1	Location 2	
1	BIS OP-61-OP-22	16.51	34.43	208.54	17.62	15.96	90.58
2	BIS OP-61-OP-37	15.47	64.52	417.07	12.94	18.33	141.65
3	BIS OP-61-♂-8	10.10	35.08	347.33	22.88	27.67	120.94
4	BIS OP-61-♂-13	12.99	40.06	308.39	11.76	11.91	101.28
5	BIS OP-61-OP-23	16.59	46.07	277.70	15.18	18.73	123.39
6	BETA 2-♀-29	17.47	36.14	206.87	15.13	18.15	119.96
7	BIS OP-61	10.68	23.97	224.44	20.04	32.09	160.13
8	PAPUA SOLOSSA	9.49	22.21	234.04	15.4	26.93	174.87
9	BETA 2	15.55	40.36	259.55	15.86	17.07	107.63
10	CANGKUANG	5.35	19.9	371.96	15.89	20	125.87
11	JAGO	9.12	31.33	343.53	13.49	21.84	161.90
12	73-6/2	11.83	30.94	261.54	13.49	17.82	132.10
	LSD (1%)	5.67	4.60		9.88	7.51	

Changes in the efficiency of dry matter translocation

The ratio between the storage root dry matter and the total dry matter referred to as harvest index, indicates dry matter partitioning efficiency to storage root in root crops like the sweet potato (Ravi and Saravanan, 2012). Therefore, the harvest index (%) can be used as a measure of the efficiency of translocation of the dry matter to the storage root. In addition to the harvest index (%), root/shoot ratio is also used to measure the level of efficiency of dry matter (Wang et al., 2017). The measurement of the harvest index and the root/shoot ratio presented in Table 6. Furthermore, using the ratio of root/shoot used to determine the type of sweet potato growth into five types: forage, low dual-purpose, high dual-purpose, low root production, and high root production following to the criteria of Leon-Velarde et al. (1997). The growth type of sweet potato when planted in rain-fed dry land (location 1) showed the forage, low dual purpose, high dual purpose and low root production type and turns into a high dual purpose and root production type when planted in paddy field (in location 2) as presented in Table 6. The forage type is characterized by a root/shoot ratio of less than 1.0, which showed the pattern of dry matter partitioning sent more than for the growth of the vines than for storage root yields; for dual purpose types when partitioning of dry matter took place in balance between the formation of storage root and the growth of vines. Otherwise, the root production type is the proportion of dry matter which is more dominantly translocated to the storage root. Change of the sweet potato growth type that is based on their root/shoot ratio is also followed by the harvest index too. The rain-fed dry land and paddy field condition relating to the soil moisture (Gajanayake and Reddy, 2016). The moisture regimes in the soil are important for maximum production of assimilate and to maintain turgidity of leaf, so as not limiting the sweet potato photosynthesis (Siqinbatu et al., 2013). The rainfed dry land and paddy field condition are also related to the agro-climatic conditions; there was an interaction between climatic factors and hydrology so that agro-climatic conditions can change the partitioning of dry matter into the storage root of sweet potato and its vines. In sweet potato, a deficit of soil moisture like what happens on dry land, is one of the crucial points of abiotic stresses, which limits growth and development and affects storage root production and yield (Van Heerden and Laurie, 2008); on the contrary in paddy fields, the adequacy of water through irrigation can increase the growth and storage root yields as achieved in this trial. In accordance with Van Heerden and Laurie (2008), photosynthesis of sweet potato exposed to drought was inhibited primarily due to stomatal closure.

Table 6. Root/shoot ratio and Harvest Index of 12 sweet potato cultivars planted at both locations (location 1 = rainfed dry land and location 2 = irrigated rice fields)

No	Clone	Root/shoot ratio		Growth type		Harvest Index (%)	
		Location 1	Location 2	Location 1	Location 2	Location 1	Location 2
1	BIS OP-61-OP-22	1.7	4.7	High dual purpose	High root production	63.75	82.59
2	BIS OP-61-OP-37	1.4	4.0	Low dual purpose	High root production	57.85	79.99
3	BIS OP-61-♂-8	0.7	2.4	Forage	Low root production	43.24	70.97
4	BIS OP-61-♂-13	1.7	5.7	High dual purpose	High root production	62.30	85.12
5	BIS OP-61-OP-23	1.6	3.7	High dual purpose	High root production	61.54	78.76
6	BETA 2-♀-29	2.1	3.5	Low root production	High root production	68.41	77.82
7	BIS OP-61	1.1	1.9	Low dual purpose	High dual purpose	53.05	65.69
8	PAPUA SOLOSSA	1.0	1.7	Forage	High dual purpose	50.89	63.48
9	BETA 2	1.4	3.8	Low dual purpose	High root production	59.53	79.90
10	CANGKUANG	0.5	2.0	Forage	High dual purpose	32.64	67.04
11	JAGO	1.2	2.9	Low dual purpose	Low root production	55.83	74.75
12	73-6/2	1.8	3.6	High dual purpose	High root production	64.76	78.63

Remark: RV ratio 0 – 1.0 = type offorage; RV ratio >1 - 1.5 = low dual purpose; RV ratio > 1.5 - 2= high dual purpose; RV ratio > 2 – 3 = low root production; and RV ratio > 3 = high root production

Conclusion

The results showed that the occurrence of changes in agroecosystems from dry land to paddy fields led to agronomic changes in sweet potato cultivars which were shown by the characteristics of storage root weight and fresh vines weight per plant and estimated yield per hectare and root/shoot ratio. Changes in agronomic performance, especially in storage root yields, can reach 2-4 times or around 206-417%.

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