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Effect of soil moisture management on the quality of wax apple

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Wax apple (Syzygium samarngense Merr.et Perry) was one of the economically planted fruits in Taiwan. This research was conducted to evaluate the effects of different soil moisture management on increasing wax apple quality. It was preceded at two different soil properties (shallow soil and alluvial soil) in Pingtung, Taiwan. Three different treatments were used at the two areas in the fruit setting stage: (1) the soil was furrowed 20 cm and immersed in water (5 cm) (FI); (2) soil moisture was monitored by tensiometer, from 15 to 25 cbar (TM); (3) Drought (DR) and the treatment of farmer usage as check (FU). The results show that the effect of TM treatment on soil available elements, the concentration of leaf elements and fruit color were all highest, and the fruit cracking percentage was lower than in other treatments in shallow soil. On the other hand, the effect of FI treatment on soil available elements, the concentration of leaf elements and fruit color were all highest, and the fruit cracking percentage was lower than for other treatments in alluvial soil. To improve the quality of wax apple, it may be treated by different management of soil moisture for the two kinds of soils at the fruit setting stage.

Key words: Wax apple, soil moisture, nutrition, fruit quality, fruit cracking.

INTRODUCTION

Wax apple is a kind of tropical fruit. In Taiwan, they are cultivated at the farmlands of Kaohsiung and Pingtung County. High quality wax apples like” Black Pearl” and “Black Diamond” have been well known for more than a decade. However, the influences of factors including climate (temperature, sunlight, and rainfall etc.), cultivation and management (pruning, flower and fruit thinning etc.), and supply of different nutrition significantly act on the growth and development, sugar content, color, and even abscission and cracking of the wax apple (Kuo et al.,2004). Besides color and sugar degree, fruit cracking is another reference index for the quality of wax apple. Sugar content and color have been notably improved in the past years. However, fruit cracking is always a quality defects. High ratio of fruit cracking has a negative impact on the marketing of wax apple (Lai, 2005). We cannot wait any more to solve this problem. There have been a bunch of achievements in fighting against fruit cracking for other fruits. For example, GA_3 (50 ppm) + NAA (50 ppm) is great for loquat in preventing fruit cracking (Yen, 1989).

Calcium fertilizer improves the fruit cracking and malformed fruits of tomato as a result of calcium deficiency (Asen, 1976). For Fuyu sweet persimmon, an appropriate rates of N- and K-Fertilizer (N: K2O=300:300 g/year/tree) is better than the high N- and K-Fertilizer rates (N: K2O=450:300 g/year/tree), which is commonly adopted by the farmers, in reducing fruit cracking at tampuk for 25% (Lai, 2001). The control of moisture content also has its impacts on fruit cracking. Markakis (1974) showed that it was possible to control the fruit cracking of pineapple by controlling the moisture content of the soil. During the period of fruit growing, instant rainfalls and bad management

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of moisture content in the soil may result in severe fruit cracking for Murcott Orange (Garcia-Luis, 1994). Soil should be kept from being excessively dry and with appropriate water content (Chang et al., 2005).

For wax apple, most of the studies on the fruit cracking are based on the utilization of nutritional agents and the cultivation management of the parts above ground. For example, Lai (2005) showed that the fruit string at the outside of the crown demonstrated the highest fruit cracking ratio on a horizontal basis. Spraying 0.3% $CaCl_2$ or $CaSO_4$ on the surface of leaves had a remarkable effect against fruit cracking. Yen et al. (2004) believed that spraying Chung-Hsin 100(CH-100) plant extract's 1000X solution in the winter helped to reduce the fruit cracking ratio by 25%. Wu (2002) found that plastic packaging demonstrated a higher fruit cracking ratio (12 to 63%) than paper packaging (10 to 45%). Rainfalls in the mature stage of wax apple result in significant fruit cracking. This is because of the fast alternation between dryness and moisture at the roots (Lai, 2005). In this study, the impacts of soil's moisture were discussed.

MATERIALS AND METHODS

The soil properties of experimental orchards

The experimental orchards were located at Kaosu and Nantzu, Pingtung, Taiwan. The soil in Kaosu is among Shashuipu series. It is a shallow soil with very good drainage properties accumulated by clay slates. This area can be characterized by rock layer or stone block layer beneath the surface soil. The soil in Nantzu belongs to Lantau series. Its alluvial soil with limited drainage capability, is based on concretion of iron and manganese accumulated by the ancient alluvial deposits of clay slates, which are alkalescent.

Experiments of water content control for soil

During mid-harvest period (December 2004), the following methods were applied accordingly: 1) FI: Digging of a channel which is 20 cm in depth on the soil around the tree. The water level in this channel was kept as 5 cm in depth; 2) TM: The moisture content of the root system at 30 cm under the ground was monitored with a buried tensionmeter as a reference for irrigation. If the reading of tensionmeter is greater than 25 cbar, the irrigation starts. If the reading is smaller than 15 cbar, the irrigation stops; 3) DR: no more irrigation was applied in and after the mid-harvest period; 4) FU (control group): The land was irrigated every 4 to 5 days to keep the soil moist.

Before the experiment and during the mid-harvest period, soil around treated plants and the 2nd mature leaf pair of the summer shoot of a non-fruit branch were analyzed. Sugar content, average fruit length, average fruit width, average fruit weight, and cracking ratio in the mature stage were investigated.

Pretreatment and analysis of soil and plants

Pretreatment and analysis of soil

After getting back soil samples, they were air dried, ground and were filtered through a 2 mm sieve. The soil was analyzed: 1) pH: water: soil = 1:1, measured by a pH meter (McLean, 1982); 2) organic content: measured by wet oxidation method described by Nelson and Sommer (1982); 3) Ca, Mg and K: K, Ca and Mg from the soil were extracted by 0.1 N HCl. The content of Ca and Mg was measured by an Atomic Absorption (AA) Spectrometer (Shimatzu, 6601F) and the content of K by a flame photometer (Corning, 401) (Baker and Suhr, 1982); 4) P was measured by molybdenum blue method (Bray No.1) (Murphy and Riley, 1962); 5) Microelements of Fe and Mn were extracted from the soil by 0.1 N HCl. Its content can be measured by an AA spectrometer (Cope and Evans, 1985).

Pretreatment and analysis of leaves (Chang, 1981)

The dusts and chemical residuals on the leaves were cleaned by tap water and put into an oven (70-75°C) which were ground after 2 to 3 days and put into a bottle. The leaves were resolved by concentrated sulphuric acid and analyzed by the following methods: 1) N: was measured by Kjeldahl method; 2) P was measured by molybdenum yellow method (Bray No.1); 3) K, Ca, Mg: Ca and Mg contents were measured by an AA spectrometer (Shimatzu, 6601F) and the K content was measured by a flame photometer (Corning, 401); 4) Fe, Mn: The concentrations of Fe and Mn were measured by an AA spectrometer.

Investigation of fruit properties and cracking ratio

In the mature stage, 20 fruits in similar size and treated by identical method were sent for the measurement of sugar content, fruit length, fruit width, and fruit weight. Color measurement was based on the L value (lightness), a value (red value), and b value (yellow value) of the widest part of the fruit by a color difference meter for every 10 fruits treated by identical method. 20 samples taken from the same tree and 60 samples in total for every treatment were investigated for cracking ratio.

RESULTS AND DISCUSSION

The influence of water content management on soil properties, leaf element concentration, and fruit quality in wax apple farm in Kaosu orchard

Table 1 demonstrates the fundamental physical and chemical properties of the soil in Kaosu before the experiment (November 2005). The soil was sandy loam. pH was 3.75. Organic content was 2.58%, P content was 108 mg/kg, K content was 121 mg/kg, Ca content was 1009 mg/kg, Mg was 140 mg/kg, Fe was 319 mg/kg and Mn was 74 mg/kg. In the harvest period (January 2006), soil pH increased a bit in the control group but decreased in all other three treatment groups. Group DR had the maximum descent of soil pH (0.34 unit), which is significantly different from the situation before the experiment. Lien (1994) thought that if the weather during the cultivation was drought, the soil would be dry and the ammonium nitrogen would become nitrate, which decreased the soil pH. Therefore, soil pH may be impacted by the environmental factors like water content and nitrogen content. As a result, the pH of DR group dropped significantly. For group FI and TM, the soil pH decreased a bit (0.16-0.18 unit) but is not considered to be significant compared to the control group.

Table 1. The influence of different soil moisture managements on soil properties in Kaosu,Pingtung.

Parameter	pH	OM (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Before treatment (November, 2005)								
	3.75^{a}	2.58^{a}	108^{b}	121^{a}	1009^{a}	140^{a}	319^{ab}	74^{a}
Harvesting stage (January, 2006)								
FI	3.57^{ab}	2.81^{a}	143^{a}	138^{a}	907^{a}	147^{a}	343^{a}	84^{a}
TM	3.59^{ab}	2.68^{a}	157^{a}	145^{a}	1142^{a}	164^{a}	336^{a}	77^{a}
DR	3.41^{b}	2.97^{a}	129^{ab}	93^{b}	757^{b}	125^{a}	301^{b}	49^{b}
FU	3.78^{a}	2.74^{a}	127^{ab}	116^{ab}	1113	151^{a}	318^{ab}	66^{ab}

FI, Furrowing and Immersing; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

Table 2. The influence of different soil moisture managements on leaf elements concentration in Kaosu,Pingtung.

Parameter	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Before treatment (November, 2005)									
	1.24^{a}	0.13^{a}	1.10^{a}	18953^{b}	1183^{a}	190^{ab}	81.3^{b}	23^{a}	37.8^{b}
Harvesting stage (January, 2006)									
FI	1.30^{a}	0.13^{a}	1.15^{a}	22380^{a}	1233^{a}	233^{a}	140^{a}	16.3^{a}	53.5^{a}
TM	1.31^{a}	0.14^{a}	1.15^{a}	21173^{a}	1355^{a}	244^{a}	143^{a}	16.8^{a}	58.8^{a}
DR	1.22^{a}	0.14^{a}	1.10^{a}	19925^{a}	1120^{a}	228^{a}	125^{a}	14.3^{a}	49.3^{a}
FU	1.28^{a}	0.11^{a}	1.15^{a}	20985^{a}	1085^{a}	245^{a}	138^{a}	16.5^{a}	51.5^{a}

FI, Furrowing and Immersing; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

For organic content, no organic fertilizer is applied in the period from pre-experiment to harvest. Therefore, the organic content increases in all of the groups but such increases are not significant. Among all the groups, group DR demonstrated a highest increase in organic content and group TM showed the lowest. Possible reason is that the decomposition of organics slows down if the water is insufficient in the soil in group DR. In group FI, TM, and the control group, soil water content was sufficient to support a normal decomposition of organics. P contents in the soil for all the groups increased, especially for group TM. For K content, group TM and FI demonstrated an increase but group DR and the control group demonstrated a descent. Among them, group TM had the highest K content and the group DR had the lowest. For Ca content, group TM and the control group demonstrated an increase but group FI and DR showed a descent. Among them, group RM had the highest Ca content while group DR had the lowest.

For Mg content, group DR turns out to be lower than pre-experiment period. Group FI, TM, and the control group were higher. For Fe content, group DR and the control group showed a lowered value than the pre-experiment period but group TM and FI demonstrated an increase. Among them, group TM hads the highest Fe content and group DR had the lowest. For Mn content, group TM and FI demonstrated an increased value in the harvest period, but the content in group DR and the control group dropped. Group FI showed the highest Mn content among all while group DR showed the lowest. As a whole, group TM hads an increased level of nutrition elements in the harvest period than in the pre-experiment period. It indicates that method TM helps to increase the effect of nutrition elements in the soil in Kaosu. Table 2 tells us the nitrogen concentration of the leaves from Kaosu in harvest period. Except for the descent in group DR, all other three groups showed an increase, when being compared to the pre-experiment period. Group TM shows a maximum increase in nitrogen concentration. For P concentration, the control group showed a descent in the harvest period and group FI keeps a balance. The rest showed an increase.

For K concentration, group DR had a descent but the rest had an increase (0.05%). For Ca concentration, values of all groups increased, especially in group FI. For Mg concentration, all of the groups increased except for group DR. Group TM showed a most significant increase. For Fe, Mn, and Zn concentrations, values increased in all of the groups, especially in group FI. On the contrary, Cu concentration showed a decent in all of the groups, especially in group DR. To summarize, group TM had a general increase in nutrition elements when compared to pre-experiment period and the other groups in the harvest period. Group DR demonstrated a lowered level of nutrition elements in both situations. This is probably because of slowed resolution of nutrition in the soil. Table 3 shows

Table 3. The influence of different soil moisture managements on waxapple quality in Kaosu, Pingtung.(January,2006).

Treatment	Sugar degree (°Brix)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g/granule)	Cracking percentage (%)	Color		
						L	a	b
FI	8.8[a]	62.3[a]	72.1[a]	134.1[a]	38.3[b]	29.9[a]	12.6[ab]	5.2[a]
TM	9.0[a]	63.2[a]	67.5[a]	115.4[a]	35.0[b]	29.9[a]	15.5[a]	6.3[a]
DR	8.1[b]	65.4[a]	68.8[a]	117.6[a]	46.7[a]	30.4[a]	10.9[b]	5.2[a]
FU	9.2[a]	62.0[a]	68.2[a]	123.9[a]	43.3[a]	31.9[a]	13.0[ab]	5.4[a]

FI, Furrowing and Immersing; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

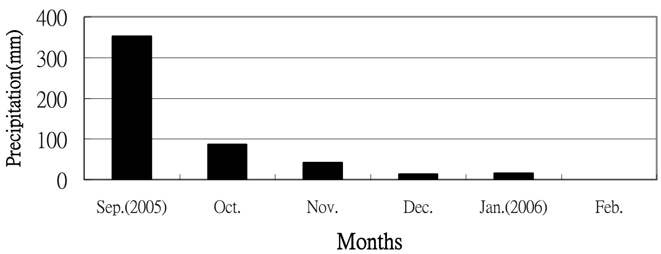

Figure 1. The average precipitation of month from September, 2005 to February, 2006 (Data from Kaohsiung district agricultural research and extension station).

that group TM and the control group had the highest sugar content in the fruit in the harvest period. Group DR turned out to be the lowest.

For fruit length, the longest value shows up in group DR and the shortest value was in group TM. Group FI demonstrated the widest value in fruit width. But the narrowest value was from group TM. For average fruit weight, group FI had the heaviest value, but group TM was the lightest. For cracking ratio, the highest value was from group DR and the lowest value was from group TM. Based on the above data, dry treatment may result in insufficient water content and therefore have a negative impact on the photosynthesis in the leaves, which produces carbohydrates. As a result, the sugar content in this group was lower than others. In group TM, the water content in the soil was always favorable. That is why the sugar content was high in this group. Although the fruits in group DR were better in length and width than that in any other group, the actual fruit density was lower than other groups due to lighter fruit weights in the group. For cracking ratio, group DR had a high value, as shown in Figure 1. A significant drop of rainfall brought drought to the soil since November 2005.

Bad fruit cracking is probably a result of drastic alteration of soil moisture by the sudden shower at the end of December 2005 and at the mid-January of 2006 before the harvest. Among all the groups, group TM showed the lowest cracking ratio. It indicates that TM method is better than others in controlling cracking ratio when cultivating wax apple in Kaosu. It will be seen from this that water control in the soil increases the effects of soil nutrition in Kaosu and helps the absorption of these nutrition. Thus, the fruit quality is improved. Although method TM is not as good as the others in fruit length, width, and weight, it does improve fruit's sugar content and lower the cracking ratio. For the L value of fruit color, the control group has the highest value while group FI and TM had the lowest. For a value (red), group TM was the highest and group DR was the lowest. Similar situation can be found for b value (yellow). It indicates that although method TM is not so good for fruit lightness, it is best for the improvement of red and yellow components in the fruit color. Method DR are worst for both red and yellow colors.

The influence of water content management on soil properties, leaf element concentration, and fruit quality in wax apple farm in Nantzu orchard

As shown in Table 4, the soil pH in all groups in Nantzu dropped in harvest period than in the pre-experiment period, especially in group DR (0.17 units). For organic content, slight descents were found in these groups. The lowest value was shown in group FI. The differences of organic content were not significant among these groups. This is because the soil in Nantzu is good in water retention. As a result, the decomposition rates of organics are quite close. The P content in the soil was increased in all groups, compared to the pre-experiment period. Group FI had the highest P content and group DR had the lowest. For K content, all groups except for group DR had increases, especially for group FI. For Ca content, all groups except for group FI were lowered, especially for the control group. For Mg content, values increased in group Fi and TM, but lowered in group DR and the control group. For Fe content, the values increased in all of the groups, especially in the group FI. For Mn content, the values dropped slightly in all of the groups. As a whole, nutrition elements in the soil were good in group FI but bad in group FR.

For nutrition elements on the leaves, concentrations of P, K, Ca, Mn, and Zn were highest in group FI. They were even higher than the concentrations in pre-experiment period. For all the measured nutrition elements except Cu, the values were lowest in group DR. They were even lower than the concentrations in pre-experiment period. Therefore, in Nantzu area, method FI is best for the soil

Table 4. The influence of different soil moisture managements on soil properties in Nantzu,Pingtung.

Parameter	pH	OM (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Before treatment (November, 2005)								
	4.01^{a}	2.44^{a}	92^{b}	143^{a}	1116^{a}	116^{b}	201^{b}	38^{a}
Harvesting stage (January, 2006)								
FI	3.93^{a}	2.39^{a}	105^{ab}	143^{a}	1077^{a}	149^{a}	235^{ab}	32^{a}
TM	3.87^{a}	2.34^{a}	130^{a}	147^{a}	1217^{a}	159^{a}	310^{a}	38^{a}
DR	3.76^{a}	2.43^{a}	96^{b}	138^{a}	1057^{a}	10^{b}	213^{b}	23^{b}
FU	3.81^{a}	2.36^{a}	114^{ab}	140^{a}	1030^{a}	114^{b}	226^{b}	33^{a}

FI, Furrowing and Immersing; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

Table 5. The influence of different soil moisture managements on leaf elements concentration in Nantzu,Pingtung.

Parameter	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Before treatment (November, 2005)									
	0.72^{b}	0.12^{a}	1.05b	8768^{b}	1418^{b}	173^{a}	243^{ab}	15^{a}	73.5^{a}
Harvesting stage (January, 2006)									
FI	1.08^{a}	0.14^{a}	1.10^{b}	9368^{ab}	1438^{b}	143^{ab}	245^{a}	13^{a}	80.3^{a}
TM	1.04^{a}	0.14^{a}	1.05^{b}	10764^{a}	1443^{b}	156^{a}	255^{a}	14^{a}	83.5^{a}
DR	0.93^{ab}	0.13^{a}	1.05^{b}	8398^{b}	1386^{b}	102^{b}	219^{b}	14^{a}	70.6^{a}
FU	1.16^{a}	0.15^{a}	1.25^{a}	10550^{a}	1763^{a}	135^{ab}	233^{ab}	18^{a}	76.3^{a}

FI, Furrow and Imerse; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

Table 6. The influence of different soil moisture managements on waxapple quality in Nantzu, Pingtung.(January,2006).

Treatment	Sugar degree (^{o}Brix)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g/granule)	Cracking percentage (%)	Color		
						L	a	b
FI	10.5^{a}	66.8^{a}	74.5^{a}	136.2^{a}	10.3^{c}	30.2^{a}	14.3^{a}	4.8^{a}
TM	8.4^{b}	65.4^{a}	71.0^{a}	130.7^{a}	25.2^{b}	33.3^{a}	10.5^{b}	5.2^{a}
DR	8.0^{b}	64.5^{a}	68.3^{a}	127.3^{a}	33.3^{a}	31.4^{a}	11.3^{b}	4.2^{a}
FU	9.4^{a}	66.6^{a}	73.1^{a}	131.9^{a}	30.0^{a}	32.3^{a}	12.5^{ab}	5.1^{a}

FI, Furrowing and Immersing; TM, Tensiometer monitoring; DR, Drought; FU, Farmer usage.

nutrition. That is why the nutrition concentrations were high in the leaves (Table 5). For fruit quality (Table 6), group FI demonstrates the highest in sugar content while group DR was the lowest. For fruit size and weight, group FI was the best and group DR was the worst. For cracking ratio, group FI showed the lowest (10.3%) and group DR showed the highest (33.3%). As shown in Figure 1, the rainfall dropped in November 2005. Bad fruit cracking is probably a result of drastic alteration of soil moisture by the sudden shower at the end of December 2005 and at the mid-January of 2006 before the harvest. The situation of fruit cracking was very bad in group DR. The L value of fruit color was highest in group TM and lowest in group FI. The a value (red) was highest in group FI and lowest in group TM. The b value (yellow) was highest in group TM and lowest in group DR. To conclude, method TM was best for lightness and yellow component of the fruit color in this area. Method FI and DR weare not so ideal. However, method FI had a best performance in red color component.

Conclusion

The quality of wax apple covers factors like color, sugar content, and fruit cracking etc. Climate and cultivation management are two factors that may impact fruit quality. Since the climate factor is hard to control, more efforts can be paid to cultivation management to improve the fruit quality. Among all cultivation managements, the improvement of tree circumstances is important. Enhanced fertilization and better water management are good to improve the quality of wax apple. In this study, different water content managements were conducted on the wax apple farms with different soil characteristics. It was found that significant differences can be found in soil properties, leaf element concentrations, as well as the fruit quality. Only the influence of water management is discussed in this study. As a matter of fact, there are much more factors that may have influences on the fruit quality of wax apple. Further study will be carried out.

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