Advance Journal of Food Science and Technology 5(4): 425-429, 2013
DOI:10.19026/ajfst.5.3284
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: October 31, 2012 Accepted: January 03, 2013 Published: April 15, 2013

Research Article

High Yield Technique of Virus-free Potato Favorite Planting in Paddy

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Abstract: To screen the best combination cultivation factors, the orthogonal test was conducted on the 6 factors of virus-free potato Favorite including sowing time, density, urea, calcium superphosphate, potassium sulfate and zinc, planted in paddy field of Xian-ning, Luo-tian and Guang-shui. The results showed that: a) experimental site had significant influence on growth period ($F = 147.08 > F_{0.01}$), sowing date had great significant influence on growth period ($F = 15.68 > F_{0.01}$), with the delay of sowing date, the growth period was short ($R_1 = 0.9851^{**}$). b) Density had great significant influence on yield ($F = 4.0 > F_{0.01}$), the yield could be increased with the density increasing ($R_2 = 0.9782^{**}$), sowing date had significant influence on yield ($F = 3.55 > F_{0.05}$). c) The maximum yield and economic return appeared at the treatment of seeding date December 10, seeding density 75000 plant/hm^2, N 75 kg/hm^2, phosphorus fertilizer 900 kg/hm^2, potassium sulfate 450 kg/hm^2 and zinc 22.5 kg/hm^2, with the yield 31185 kg/hm^2 and economic benefit 26833 Yuan/hm^2.

Keywords: Calcium superphosphate, density, potassium sulfate, potato, sowing date, urea, zinc

INTRODUCTION

Potato is a kind of cash crop that can be used for grain, vegetables, industrial raw and so on, and have characteristics of high yield, abundant nutrition and adaptability (Cui *et al*., 2010). The potato is the main food crops in mountain area and one of the major developing crops in plain lake area (Wen *et al*., 2008; Xiang *et al*., 2011). Jianghan plain is major rice production area and one of major area of developing potatoes. High technology research of potatoes can promote high production and improve the overall production efficiency of paddy fields. In 2010, in the support of agriculture science and technology promotion station of Hubei, we study high yield technique of virus-free potato favorite which is planted in paddy field and obtain initial results.

MATERIALS AND METHODS

Experimental material: Tested cultivar was virus-free potato Favorite, which was provided by agriculture science and technology promotion station of Hubei.

Experimental design: The experiment adopted orthogonal design and chose L_{25} (5^6) orthogonal tables. Tests were carried out in the country of Xian-ning, Luo-tian and Guang-shui. All treatments were applied potassium Sulfate complex manure (N:P:K = 16:16:16) amount of 1125 kg/hm^2 as basal dressing. The experiment was conducted to choose sowing period, density, the amount of urea, superphosphate, potassium sulfate and zinc as experimental factors respectively. Besides that, each experimental factor has five levels, as shown in Table 1.

In the experiment, all plots were covered by film. The area of each plot was 12.6 m^2 (6×2.1 m); we planted three rows potatoes each plot, with single line in a row. We took the means of ridge culture, the ridge was 35 cm tall and the sowing depth was 12 to 15 cm. We planted 2 to 3 guard rows around test. We put potato seeds cut tuber before sowing 2-3 days, and ensure each tuber had 1 to 2 bud eyes. We mixed the seeds with thiophanate methyl and the ratio was 1.5:100. After mixing the seeds, we dried seeds in the sun and lest seed decay. We chose paddies as experimental fields which have some abilities of water logging resistance, soil loosened and fertility uniform. All fertilizer was used as seed fertilizer which was put between two potato tubers.

RESULTS AND DISCUSSION

Growing process: There were obvious differences in different growing stages of 3 pilots (Table 2). The seedling stage and maturity of Luo-tian are eariler than

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Table 1: Experimental factors and levels

Items	Level 1	Level 2	Level 3	Level 4	Level 5
Sowing date (month/day)	12/10	12/20	12/30	1/9	1/19
Density (10^4 plant/hm^2)	4.5	5.25	6	6.75	7.5
Urea (kg/hm^2)	0	75	150	225	300
Calcium superphosphate (kg/hm^2)	450	900	1350	1800	2250
Potassium sulfate (kg/hm^2)	300	375	450	525	600
Zinc (kg/hm^2)	0	7.50	15	22.50	30

Table 2: Phenophase questionnaire of different pilots and treatments

		Seeding stage (month/day)			Maturity (month/day)			Whole growth period (days)			
Treatments	Sowing date (month/day)	Xian-ning	Luo-tian	Guang-shui	Xian-ning	Luo-tian	Guang-shui	Xian-ning	Luo-tian	Guang-shui	Average
1	12/10	3/14	2/24	3/5	5/10	5/2	5/7	57	68	63	62.7
2	12/20	3/16	2/20	3/10	5/9	5/2	5/7	54	72	58	61.3
3	12/30	3/18	2/25	3/10	5/10	5/2	5/7	53	67	58	59.3
4	1/10	3/22	3/3	3/15	5/15	5/2	5/10	54	60	56	56.7
5	1/20	3/25	2/22	3/15	5/15	5/2	5/10	51	70	56	59.0
6	1/20	3/25	3/1	3/10	5/15	5/2	5/10	51	62	61	58.0
7	12/10	3/14	2/25	3/5	5/8	5/2	5/7	55	67	63	61.7
8	12/20	3/16	2/24	3/10	5/9	5/2	5/7	54	68	58	60.0
9	12/30	3/19	2/25	3/15	5/10	5/2	5/10	52	67	56	58.3
10	1/10	3/22	2/27	3/15	5/13	5/2	5/10	52	65	56	57.7
11	1/10	3/22	2/26	3/15	5/13	5/2	5/10	52	66	56	58.0
12	1/20	3/25	3/3	3/15	5/14	5/2	5/10	50	60	56	55.3
13	12/10	3/14	2/14	3/5	5/8	5/2	5/7	55	78	63	65.3
14	12/20	3/16	2/27	3/5	5/9	5/2	5/7	54	65	63	60.7
15	12/30	3/20	3/3	3/10	5/11	5/2	5/7	52	60	58	56.7
16	12/30	3/20	2/27	3/15	5/10	5/2	5/7	51	65	53	56.3
17	1/10	3/21	3/3	3/15	5/13	5/2	5/10	53	60	56	56.3
18	1/20	3/25	2/27	3/15	5/15	5/2	5/10	51	65	56	57.3
19	12/10	3/14	2/24	3/5	5/7	5/2	5/7	54	68	63	61.7
20	12/20	3/16	2/25	3/5	5/8	5/2	5/7	53	67	63	61.0
21	12/20	3/17	2/25	3/5	5/9	5/2	5/7	53	67	63	61.0
22	12/30	3/20	2/26	3/15	5/11	5/2	5/7	52	66	53	57.0
23	1/10	3/22	3/3	3/15	5/13	5/2	5/10	52	60	56	56.0
24	1/20	3/25	3/8	3/15	5/14	5/2	5/10	50	55	56	53.7
25	12/10	3/14	2/22	3/5	5/7	5/2	5/7	54	70	63	62.3

Table 3: The economic characters comparison of different pilots and treatment

Treatment	Tuber weight per plant (kg)	Harvested hole per plot	Yield (kg/hm^2)	Commodity potato rate (%)
1	0.51	49.7	19425	64.1
2	0.42	57.7	17745	56.6
3	0.54	65.7	24495	71.5
4	0.43	70.3	23175	59.1
5	0.38	87.3	26280	75.7
6	0.40	82.0	25470	67.9
7	0.53	85.7	31185	62.6
8	0.36	51.0	13650	63.1
9	0.44	62.3	23505	77.7
10	0.39	64.0	18570	60.9
11	0.39	61.0	19215	55.9
12	0.41	67.7	22515	64.0
13	0.41	77.3	30960	60.9
14	0.39	72.3	21315	62.3
15	0.57	55.3	22005	70.6
16	0.37	79.3	22410	64.9
17	0.44	55.3	18390	61.7
18	0.36	61.3	17520	73.9
19	0.38	71.7	22695	66.8
20	0.37	63.7	18645	68.9
21	0.43	68.0	21210	70.1
22	0.43	74.0	23085	68.6
23	0.40	68.7	22050	64.2
24	0.41	62.7	20190	66.7
25	0.46	58.7	20040	55.9
Mean	0.42	66.9	21825	65.4

The mean is average of the 3 sites

Guang-shui and Xian-ning. The average growth period of potato planted in Luo-tian was 65.5 days which was the longest among three sites; Xian-ning's was the shortest which was 52.8 days. There were obvious differences among treatments too. The growth period of treatment 13 was 65.3 days which was the longest, the second was treatment 1 and the shortest one was treatment 24. Further analysis on the growing stage indicates that experimental site ($F = 147.08 > F_{0.01}$) and sowing date ($F = 15.68 > F_{0.01}$) had great significant influence on growth period respectively, with the delay of sowing date, the growth period was short. The differences of other 5 factors did not reach significant level. The relationship between sowing date and growth

period is $y = 0.0043x^2 - 348.82x + 7E + 06$ (y: growth period, x: sowing date).

The correlative analysis shows that with the delay of sowing date, the growth period is short in the test range ($R_1 = 0.9851^{**}$). The shortest growth period is 56.7 days, which sowing date is January 19.

Economic characters and yield: There were obvious differences in economic characters of different treatments (Table 3). The tuber weight per plant distribution was at 0.36-0.57 kg, treatment 15 was the heaviest and the least weight ones were treatment 8 and 18. The harvested hole per plot distribution was from 49.7 to 87.3 holes. Among them, treatment 5 was the most; the least one was treatment 1. The yield of plot distribution was from 13650 to 31185 kg/hm^2. The highest one was treatment 7 and the lowest one was treatment 8. The commodity potato rate distribution was at 55.9-77.7%, treatment 9 was the highest and the lowest ones were treatment 11 and 25. In all the treatments, the economic characters of treatment 7 were the best. In addition, due to different planting environment of the different sites, there were obvious differences in economic characters of the 3 sites. The economic characters of potato planted in Guang-shui were better than the other two.

The data of yield were assessed by analysis of variance, the results showed that density had great significant influence on yield ($F = 4.12 > F_{0.01}$), sowing date had significant influence on yield ($F = 3.55 > F_{0.05}$). The differences of other 5 factors did not reach significant level on yield and commodity potato rate. Therefore, the main factors that influence the potato yield are density and sowing date.

A further study showed that there is high correlation between density and yield (Fig. 1) and the correlation between them was significant ($R_2 =$

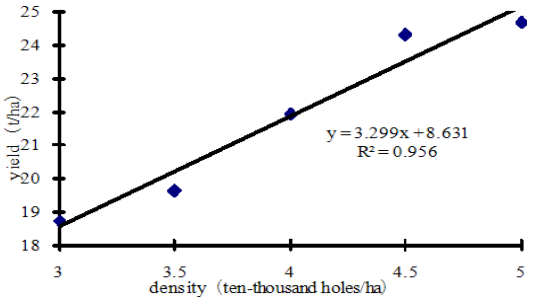

Fig. 1: The influences of density on yield

Table 4: Total yield and marketable tuber yield comparison of different treatments

Treatment	Total yield kg/hm^2	Significant level 5%	Significant level 1%	Treatment	Marketable tuber yield kg/hm^2	Significant level 5%	Significant level 1%
7	31185.0	a	A	5	19965.0	a	A
13	30964.5	ab	AB	7	19681.5	ab	A
5	26280.0	abc	ABC	13	18858.0	abc	AB
6	25474.5	abcd	ABC	9	18445.5	abc	AB
3	24495.0	abcd	ABCD	3	17652.0	abcd	ABC
9	23500.5	abcd	ABCD	6	17224.5	abcde	ABC
4	23179.5	abcd	ABCD	22	16575.0	abcde	ABC
22	23080.5	abcd	ABCD	15	15901.5	abcde	ABC
19	22690.5	bcd	ABCD	19	15430.5	abcdef	ABC
12	22510.5	cd	ABCD	21	15246.0	abcdef	ABC
16	22414.5	cd	ABCD	16	14548.5	abcdef	ABC
23	22045.5	cd	ABCD	14	14254.5	abcdef	ABC
15	22005.0	cd	ABCD	23	14160.0	abcdef	ABC
14	21319.5	cde	ABCD	12	13930.5	abcdef	ABC
21	21214.5	cde	ABCD	4	13486.5	abcdef	ABC
24	20190.0	cde	ABCD	24	13458.0	abcdef	ABC
25	20044.5	cde	BCD	20	12952.5	bcdef	ABC
1	19425.0	cde	CD	18	12825.0	bcdef	ABC
11	19215.0	cde	CD	1	12691.5	cdef	ABC
20	18640.5	cde	CD	17	11373.0	def	ABC
10	18574.5	cde	CD	25	11248.5	def	ABC
17	18390.0	cde	CD	10	11140.5	def	ABC
2	17749.5	de	CD	11	10434.0	ef	BC
18	17515.5	de	CD	2	10425.0	ef	BC
8	13650.0	e	D	8	8760.0	f	C

The data is average of the 3 sites

Table 5: Range analysis of yield

Factor	Level 1	Level 2	Level 3	Level 4	Level 5	Min.	Max.	Range R	Adjusted R′
Sowing date	1657.47	1234.333	1539.933	1352.07	1492.93	1234.33	1657.47	423.133	378.460
Density	1248.80	1307.000	1459.800	1617.87	1643.27	1248.80	1643.27	394.467	352.820
Nitrogen	1481.73	1498.467	1546.867	1328.67	1421.00	1328.67	1546.87	218.200	195.160
Phosphorus	1436.60	1505.533	1448.933	1478.40	1407.27	1407.27	1505.53	98.2667	87.892
Potassium	1332.20	1466.200	1516.333	1357.33	1604.67	1332.20	1604.67	272.467	243.700
Zinc	1414.93	1465.267	1463.000	1534.67	1398.87	1398.87	1534.67	135.800	121.460

The data is average of the 3 sites; Min.: Minimum; Max.: Maximum

Table 6: Economic benefit comparison

Treatment	Input	Marketable tuber value	Minituber value	Net output value
7	9926	27555	9204	26833
13	11291	26402	9686	24798
6	9723	24113	6600	20990
5	13383	27951	5052	19620
3	10784	24712	5474	19403
22	10319	23205	5206	18092
9	12149	25825	4044	17720
16	10229	20367	6293	16432
19	11381	21604	5808	16031
21	10670	21344	4776	15450
12	11088	19504	6864	15280
1	8186	17769	5388	14971
15	12239	22263	4884	14908
23	11244	19824	6310	14890
14	10940	19955	5652	14668
4	12084	18882	7754	14552
24	12543	18842	5386	11685
11	10164	14608	7025	11469
2	9485	14595	5861	10971
18	11178	17955	3754	10531
20	12305	18134	4550	10379
25	12746	15747	7037	10039
17	11529	15923	5614	10008
10	11799	15598	5947	9746
8	11225	12264	3912	4952

The price of marketable tuber and minituber are 1.4 and 0.8 Yuan/kg, respectively; Input includes fertilizer, seed, mulching film, labor cost and so on

0.9782**; y = 3.2997x + 8.6316) When density increased by 10000 plants/hm^2, the yield increased by 3.2997t.

From the Table 4, we can see that the difference of total yield of different treatments reached extremely significant level. The total yield of treatment 7 was highest, which was 31185 kg/hm^2. The differences ($p<0.01$) between treatment 7 and treatment 1, 2, 8, 10, 11, 17, 18, 20 and 25 were extremely significant and there were a significant difference ($p<0.05$) between treatment 7 and treatment 12, 13, 14, 15, 16, 19, 21, 22, 23 and 24, respectively. The treatment 13 was second, which was 30964.5 kg/hm^2. The difference of marketable tuber yield of different treatments reached extremely significant level too. The marketable tuber yield of treatment 5 was highest, which was 19965 kg/hm^2. The differences ($p<0.01$) between treatment 5 and treatment 2, 8 and 11 were extremely significant, the treatment 7 was second, which was 19681.5 kg/hm^2. From above results, the total yield and marketable tuber yield of treatment 7 and 5 were all top two, and the two combinations could significantly increase grain yield.

In order to sift the best combination, the data of yield was assessed by using range analysis, the results showed that the range R of sowing date and density were top two, the result was consistent with the variance analysis. Therefore, priority should be given to the two factors, when we choice the best combination. From the Table 5, we should select level 1 of sowing date and level 5 of density. Combined with the orthogonal design table we could see treatment 7 was the best combination, which was consistent with the actual output.

Economic benefit analysis: From the Table 6, the net output value of treatment 7 was the highest with 26833 RMB Yuan/hm^2; the next one was treatment 13 which is 24798 RMB Yuan/hm^2. The net output value of treatment 5 was the sixth with 19620 RMB Yuan/hm^2, although the marketable tuber value was the highest. There is great difference in treatment 5 and 7. The yield of treatment 8 was low and input was high, leading to the net output value was the lowest. Treatment 7 can extremely improve the economic benefit of potato in the test range, so the cultivation combination should be applied in production, and enhanced the economic income of farmers.

CONCLUSION

Conclusion can be made through the three different representative area experiments in 2010:

- In 25 treatments, the economic benefit of treatment 7, 13 and 6 were better than others, which should be applied in production.
- Experimental unit had great significant influence on growth period (F = 147.08**). Similarly, sowing date had great significant influence on growth period (F = 15.68**), with the delay of sowing date, the growth period was short (r_1 = 0.9851). In the range of the test, the growth period of which planted on December 10 was the shortest.

- Density had great significant influence on yield (F = 4.12**), the yield could be increased with the density increasing (r_2 = 0.9782), when density increased by 10 000 plants/hm^2, the yield increased by 3.2997t. Sowing date had significant influence on yield (F = 3.55*).

Discussion: Potato's yield component is the product of plant numbers per unit area and single plant yield, which are related to density (Chen and Su, 2009). In definite range of density, the yield could be increased with the density increasing, beyond the scope, if the density are continued to increase, the yield will decrease (Jiang, 2005). It suggested that the maximal density of experiment does not reach the highest of reasonable range (Fig. 1). Therefore, the density of potato still has room to be improved on the basis of experiment. In addition, when doing experiment, we ignore the interactions between various factors. If the interactions were taken into consideration, we need to further study.

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