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Effect of rice harvest on milling yield and grain breakage

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Abstract. Five rice varieties were grown during 1989 and 1990 to estimate the total milling yield and the grain breakage at six different harvest times. The highest total milling yield was obtained at the 3rd harvest time when the grain moisture content was 17.92%, while the lowest one at the 1st harvest time when the grain moisture content was 22.16%. The highest grain breakage was observed during the 6th harvest time when the grain moisture content was 13.89%, while the lowest one during the 1st harvest time. Concerning the different varieties, it was found that total milling yield was correlated with grain breakage only in the variety Strymonas r=-0.40**, while total milling yield and grain moisture content were correlated only in the variety Ispaniki A r=-0.29*. However, grain breakage and grain moisture content were correlated in all the varieties studied (Axios and Evropi r=-0.83**, Ispaniki A r=-0.89**, Roxani r=-0.74** and Strymonas r=-0.94**).The regression lines fitted for each combination of the above mentioned three variables (total milling yield, grain breakage, grain moisture content) indicated that there was an optimum harvest time for each variety to achieve the highest total milling yield with the lowest grain breakage.

Keywords. Total milling yield – Grain breakage – Rice – Variety – Harvest time – Grain moisture content

I – Introduction

The market value of rough rice is mainly based on its milling yield or on its milling quality. The milling yield is determined from the quantity of whole kernels (head rice) and broken kernels produced during the milling of rough rice. Therefore, head, broken and total milled rice are usually expressed as a percentage of the total quantity of the rough rice subjected to the milling procedure.

Reduced grain breakage during milling is particularly very important, because the value of broken milled rice is only 30–50% of the value of head milled rice. The breakage is dependent on the variety, size and shape of grains, the existence of pearl (Bhashyam et al., 1985), the rate and time of nitrogen application (Mengel and Leonard, 1977) as well as on the cylinder speed of threshing (Dilday, 1989). It is significantly affected by the weather conditions prevailing just before the harvest and by the grain moisture content during harvesting (Govindaswami and Ghosh, 1970; 1972). Generally, when the weather conditions prevailing in the rice fields are characterized by sunshine during the day and high relative humidity at night, the grains dry relatively quickly during the day but reabsorb moisture during the night. These conditions provoke transverse fissures in the grains and increase breakage during their milling. The varieties show different resistance to this phenomenon also known as sun-crack (Huysmans, 1965).

The harvest time greatly affects the breakage of grains, as it was ascertained in an experiment of 10 varieties in Surinam. The delay of harvest resulted in a high breakage due to the creation of fissures in the grains. A very good criterion for the determination of the optimum harvest time of grains was found to be their moisture content, which was 19–21% in the early afternoon during dry weather conditions. After the optimum maturity of rice, the 1% reduction of grain moisture content corresponds to 2% increase of grain breakage (Have, 1967). In countries where rice producers have less access to moisture-measurement devices, the optimum time for harvesting may be specified by days after flowering. So, the optimum harvest time of the Patna cultivar grown in India was determined to be between 26–29 days after flowering. At this time, the field moisture content was between 22.5–25% (Bose and Chattopadhyay, 1976).

In one experiment in Texas (USA), where two long-grain (Lebonnet and Labelle) and two medium-grain (Brazos and Nato) cultivars were evaluated, it was found that the percentage of total milled rice increased with delay in harvest time, but the percentage of head rice reached the maximum at an intermediate harvest time, followed by a rapid decline with further delay in harvesting. It was concluded that both the Brazos and Lebonnet varieties required a higher moisture content at harvest than the Labelle and Nato in order to maintain the same percentage of head rice. Also, it was ascertained that a rapid decline in head rice yield occurred when the grains of Lebonnet and Brazos reached about 17% moisture content and when those of Labelle and Nato reached 14% moisture content (Calderwood et al., 1980).

It is obvious from the above that the grain moisture content at harvest has an influence on total milling yield and grain breakage. Until recently, there was no study on the behaviour of the Greek rice varieties in the presence of those factors.

The objective of this research was to study the effect of harvest time on the total milling yield and grain breakage of Greek rice varieties (Japonica type).

II – Material and methods

Two experiments were carried out in 1989 and 1990 at the Cereal Institute Farm of Kalochori-Thessaloniki on a silt loam soil with a pH of 7.5 and 1.6% organic matter. The field experiments were conducted with the long-grain varieties Axios, Evropi, Roxani and Strymonas and the medium-grain variety Ispaniki A. The experimental design for each test was a split plot with four replications. Rice seed was drilled at approximately 3.2 g/m in plots of 14 rows 5 m long and 25 cm apart. The seeding of the above varieties was performed in both years during mid-May. Plants were harvested at the following six dates: 18/9, 24/9, 30/9, 6/10, 12/10 and 18/10 for 1989 and at 15/9, 21/9, 27/9, 3/10, 9/10 and 15/10 for 1990. The harvesting started when the grain moisture content was approximately 22%. Two different rows 4.5 m long, coming from the 12 interval rows, were hand harvested between at midday when the grains were free of dew and surface moisture. The two external rows of each plot were not harvested.

A machine-thresher (F. Walter-H. Wintersteiger) was used to separate the grains from straw. After threshing, the samples were passed through a vibration screen to remove the leaves and stems, while the unfilled grains were removed by aspiration. After cleaning, the grain moisture content was determined by a Steinlite moisture meter. Then, the samples were dried until their moisture reached the level of 13%. Two sub-samples of 200 g from each sample were dehulled by a mill of Olmia type and their milling yield was determined according to the standard procedure of rice graders. Afterwards, total milling yield and grain breakage were expressed as percentages, while their means were compared by using the Duncan's multiple range test.

III – Results and discussion

The analysis of variance indicated that there was significant effect for total milling yield and grain breakage due to year, variety, harvest time and also due to the interaction between year x variety, year x harvest time, variety x harvest time and year x variety x harvest time for total milling yield and grain breakage *(Table 1).*

The total milling yield was higher in 1990 than in 1989. This could be due to the extended period of sunny days during the second year, which probably resulted in higher milling yield with respect to hulls. The significant difference observed between the two years for the grain breakage should be due to the drier weather conditions prevailing in 1990 compared to that of 1989 *(Table 2)*. In this year, the sun-crack was perhaps more intense and created therefore more fissures in the grains.

The highest total milling yield was achieved in the medium-grain variety Ispaniki A, while the lowest one in the long-grain variety Roxani *(Table 3)*. The rest of the varieties produced intermediate milling yield. The highest grain breakage was found in the variety Axios, the lowest one in the varieties Evropi and Strymonas. The Roxani and Ispaniki A varieties showed intermediate grain breakage compared to the above mentioned ones. The higher grain breakage of the long variety Axios, which contains 100% pearl, compared to that of the long-grain variety Roxani, could be due to the fact that the variety Axios is 20 days more precocious than Roxani and probably due to its intense sun-crack which created more fissures in the grains. The varieties Evropi and Strymonas, which contain 80% and 60% pearl respectively, show fissures to a less extent and consequently lower grain breakage. However, for unknown reasons, the variety Ispaniki A, although containing only 10% pearl, shows significantly higher grain breakage.

The study of the six different harvest times indicated that the total milling yield had the highest rate at the 3rd harvest time, where the grain moisture content was about 18% *(Table 4)*. The total milling yield was similar for both the 2nd and 4th harvest times, but lower than that of the 3rd one. The reduction of the total milling yield continued at the 5th harvest time and even more at the 6th one. However, the lowest milling yield was obtained at the 1st harvest time during which the grain moisture content was greater than 22%. The relatively lower total milling yield at the two first harvest times is probably due to the presence of unripe, light and deformed grains. These grains have higher percentage of hulls in relation to normal ones and they break to pieces during the milling. Therefore, they finally produce less quantities of white milled rice (Govinvaswami and Ghosh, 1972). The reduced trend of total milling yield during the 4th, 5th and 6th harvest times (grain moisture content lower than 16%) was probably due to the higher grain breakage during the milling and due to the higher production of very small pieces of the kernels. The results are in agreement with those reported by Berrio and Cuevas-Perez (1989) for other varieties. According to them, the 2-weeks delay for harvesting resulted in a 3% reduction of the total milling yield, which is in contrast with results found by Govindaswami and Ghosh (1972).

The lowest grain breakage was obtained at the 1st harvest time when the grain moisture content was about 22%. Then, it was increased at the following harvest times and reached the highest value the 6th time, when the grain moisture content was about 14% *(Table 4)*. These results are in agreement with those found by other researchers (Berrio and Cuevas-Perez, 1989; Bose and Chattopadhyay, 1976; Faulker and Wratten, 1965; Karayiannis et al., 1976; Kester et al., 1963). According to them, the delay of harvesting resulted in grains with reduced moisture content and consequently increased grain breakage. According to the above researchers, the harvest time for lowest breakage was different for each variety, but it was always obtained when the grain moisture content ranged between 17 and 25%.

The correlation coefficients of the various combinations of the variables examined (total milling yield, grain breakage, grain moisture content) are shown in *Table 5*. Correlation coefficient was not significant between the first two variables in the varieties studied, with the exception of the variety Strymonas that showed negative correlation (r = -0.40**). This means that as the grain breakage of the above variety is increasing its milling yield is decreasing. Also, negative correlation was observed between the 1st and 3rd variable for the variety Ispaniki A (r= -0.29*), which means that as grain moisture content is decreasing the milling yield is increasing. Finally, negative correlation was observed between the 2nd and 3rd variables for all the varieties examined. The correlation coefficients were the following: Axios r= -0.83**, Evropi r= - 0.83**, Ispaniki A r= -0.89**, Roxani r= -0.74** and Strymonas r= -0.94**. These data allow the conclusion that as the grain moisture content of the aforementioned varieties is reducing the grain breakage is increasing. The regression equations found for all the possible combinations of the above variables determined for each variety are presented in *Table 6*. The regression equations between total milling yield and grain breakage show that the increase of one unit of the second variable of the varieties Axios, Evropi, Ispaniki A and Strymonas decreased the first variable by 1.09, 0.23, 0.13 and 0.12, respectively. However, there was not any correlation for the variety Roxani. Concerning the regression equations between total milling yield and grain moisture content, it is shown that a decrease of one unit in the grain moisture content of the varieties Axios, Evropi and Strymonas decreased the total milling yield by 0.50, 0.15 and 0.58 respectively, while one unit decrease of the grain moisture content in the varieties Ispaniki A and Roxani resulted in an increase of the total milling yield by 0.55 and 0.05, respectively. Finally, the regression equations between grain breakage and grain moisture content show that a decrease of one unit on the grain moisture content of the varieties Axios, Evropi, Ispaniki A, Roxani and Strymonas increased their total milling yield by 0.37, 0.71, 0.50, 0.74 and 0.70, respectively.

The correlation coefficients of the regressed variables (total milling yield, grain breakage, grain moisture content) for each harvest time are shown in *Table 7*. There was negative correlation (r = -0.44**) between total milling yield and grain breakage only at the 3rd harvest time, during which the grain moisture content was 17.92%. However, there was no significant correlation between total milling yield and grain moisture content at any of the harvest times studied. Finally, the following negative correlations were found between grain breakage and grain moisture content of the following harvest times: 2nd r= -0.47**, 3rd r= -0.49**, 4th r= -0.49**, 5th r= -0.34*. These results show that as the grain moisture content was decreased below 20.38%, the grain breakage was increased. The regression equations found for each combination of the three variables mentioned above for the harvesting times are presented in *Table 8*. The regression equations between total milling yield and grain breakage show that as the grain breakage is increasing by one unit the milling yield is declining by 0.12, 0.07, 0.48, 0.28 and 0.18 at the 1st, 2nd, 3rd, 4th and 5th harvest time, respectively, while for the 6th harvest time as the grain breakage is increasing by one unit the milling yield is increasing by 0,16. The regression equations between total milling yield and grain moisture content indicate that for the 1st and 2nd harvest times, as the grain moisture content is decreasing by one unit, the total milling yield is increasing by 0.03 and 0.08, respectively. However, for the 3rd, 4th, 5th and 6th harvest times as the grain moisture content is decreasing by one unit, the total milling yield is also decreasing by 0,02, 0,05, 0,07 and 0,03, respectively. Finally, the regression equations between grain breakage and grain moisture content show that as the grain moisture content at the 2nd, 3rd, 4th, 5th and 6th harvest times is decreasing by one unit, its grain breakage is increasing by 0.35, 0.26, 0.14, 0.09 and 0.01, respectively. At the 1st harvest time it is shown that as the grain moisture content is decreasing by one unit, its grain breakage is decreasing by 0.04. In conclusion, the results of this study demonstrated clearly that the grain breakage was not significant when the grain moisture content was higher than 22.16% (1st harvest time) but it was increased with decreasing the grain moisture content.

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Table 1. Analysis of variance of total milling yield and grain breakage as affected by five rice varieties and six harvest times

Source	df	Mean squares Total milling yield	Grain breakage
Year	1	147.74**	608.34 **
Variety	4	454.21**	337.63 **
Year x Variety	4	3.00**	28.55 **
Error	27	0.59	0.59
Harvest time	5	45.31**	766.02 **
Year x Harvest time	5	17.05**	24.41 **
Variety x Harvest time	20	2.71**	20.89 **
Year x Variety x Harvest time	20	0.98**	3.89 **
Error	150	0.32	0.41
C.V.%		0.84	5.72

** Significant at P ≤ 0.01

Table 2. Total milling yield and grain breakage as affected by growing period. Means are averaged over five varieties and six harvest times

Growing period	Total milling yield (%)	Grain breakage (%)
1989	66.24 a	9.59 a
1990	67.81 b	12.77 b

Means of each column followed by different letter indicate significant differences at P ≤ 0.01.

Table 3. Total milling yield and grain breakage of five rice varieties. Means are averaged over six harvest times

Variety	Total milling yield (%)	Grain breakage (%)
Ispaniki A	69.96 a	11.96 b
Evropi	69.24 b	9.32 d
Strymonas	68.41 c	9.08 d
Axios	64.55 d	15.72 a
Roxani	62.99 e	9.78 c

Means of each column followed by the same letter in the same column are not significantly different at P ≤ 0.01.

Table 4. Total milling yield and grain breakage at six different harvest times. Means are averaged over five varieties

Harvest time	Grain moisture content (%)	Total milling yield (%)	Grain breakage (%)
1st	22.16	65.71 e	6.53 d
2nd	20.38	67.60 b	7.22 e
3rd	17.92	68.60 a	9.28 d
4th	16.08	67.57 b	11.86 c
5th	15.17	66.54 c	14.36 b
6th	13.89	66.11 d	17.83 a

Means of each column followed by the same letter in the same column are not significantly different at P ≤ 0.01

Table 5. Correlation coefficients between total milling yield (Y) and grain breakage (X), total milling yield (Y) and grain moisture content (Z) and grain breakage (X) and grain moisture content (Z) for each variety

Variables	Variety Axios	Evropi	Ispaniki A	Roxani	Strymonas
(Y) x (X)	-0.26 ns	-0.11 ns	-0.04 ns	0.00 ns	-0.40 **
(Y) x (Z)	0.27 ns	0.08 ns	-0.29 *	-0.03 ns	0.30 ns
(X) x (Z)	-0.83 **	-0.83 **	-0.89 **	-0.74 **	-0.94 **

* Significant at ≤ P0.05
** Significant at ≤ P0.01

Table 6. Regression equations between total milling yield (Y) and grain breakage (X), total milling yield (Y) and grain moisture content (Z) and grain breakage (X) and grain moisture content (Z) for each variety

Variables	Variety				
	Axios	Evropi	Ispaniki A	Roxani	Strymonas
(Y) x (X)	Y=86.27-1.09X	Y=24.88-0.23X	Y=20.9-0.13X	Y=9.58+0.00X	Y=85.90-1.12X
(Y) x (Z)	Y=-15.94+0.50Z	Y=6.95+0.15Z	Y=57.52-0.55Z	Y=21.38-0.05Z	Y=22.58+0.58Z
(X) x (Z)	X=22.36-0.37Z	X=24.06-0.71Z	X=24.66-0.50Z	X=25.50-0.74Z	X=23.32-0.70Z

Table 7. Correlation coefficients between total milling yield (Y) and grain breakage (X), total milling yield (Y) and grain moisture content (Z) and grain breakage (X) and grain moisture content (Z) for each harvest time

Variables	Harvest time		
	1st	2nd	3rd
(Y) x (X)	-0.23 ns	-0.10 ns	-0.44 **
(Y) x (Z)	-0.11 ns	-0.16 ns	+0.03 ns
(X) x (Z)	+0.07 ns	-0.47 **	-0.49 **
	4th	**5th**	**6th**
(Y) x (X)	-0.23 ns	-0.13 ns	+0.09 ns
(Y) x (Z)	+0.14 ns	+0.19 ns	+0.13 ns
(X) x (Z)	-0.49 **	-0.34 *	-0.02 ns

* Significant at ≤ P0.05
** Significant at ≤ P0.01

Table 8. Regression equations between total milling yield (Y) and grain breakage (X), total milling yield (Y) and grain moisture content (Z) and grain breakage (X) and grain moisture content (Z) for each harvest time

Variables	Harvest time		
	1st	2nd	3rd
(Y) x (X)	Y=14.37-0.12X	Y=12.08-0.07X	Y=42.73-0.48X
(Y) x (Z)	Y=24.13-0.03Z	Y=26.00-0.08Z	Y=16.72+0.02Z
(X) x (Z)	X=21.92+0.04Z	X=22.91-0.35Z	X=20.30-0.26Z
	4th	**5th**	**6th**
(Y) x (X)	Y=30.52-0.28X	Y=26.39-0.18X	Y=7.15+0.16X
(Y) x (Z)	Y=12.70+0.05Z	Y=10.61+0.07Z	Y=11.81+0.03Z
(X) x (Z)	X=17.72-0.14Z	X=16.42-0.09Z	X=13.95-0.01Z

Notes:

Fertilization. Our research has shown that rice in Greece needs the following fertilization rates: Nitrogen 150 kg/ha, P_2O_5 60 kg/ha and K_2O 80 kg/ha. Nitrogen must be applied three times: 40% before seeding, 30% during tillering and the rest at panicle initiation. Phosphorus and Potassium must be applied before seeding.

Irrigation. Flooded irrigation is the method used for rice fields. It has been found that 1100–1400 mm of water is necessary for a satisfactory yield. Irrigation is realised according to an alternate programme of four days with irrigation and four days without. Soil levelling based on laser rays was better than with the conventional leveller and resulted in an improved water economy and better seed germination as well.

Harvest time. Rice farmers try to harvest the paddy when the moisture content of grains is lower than 17% in order to avoid the expense of rice drying. This results in a lower total milling yield and a higher grain breakage. According to our research work, the highest milling yield was achieved at a grain moisture content of 18%, while the lowest yield was obtained at a grain moisture content of 22%. The highest grain breakage was obtained at a grain moisture content of 14% and the lowest one at a grain moisture content of 22%.