VARIABILITY OF FRUIT PRODUCTION AND PRODUCTIVITY FEATURES UNDER THE INFLUENCE OF SOILS MAINTENANCE SYSTEMS IN THE ORCHARD

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Abstract

Naturally, new apple plantations established in the last 10 years include other varieties than those that are traditionally grown. These varieties are most of Western European origin and already know a considerable expansion in horticulture developed EU countries.

All five new varieties of apple (Rajka, Rubinola, Topaz, Otava and Goldstar), tested in the research, find in the respective basin, favourable pedoclimatic growing conditions

All new varieties prefer bare fallow (classic or with herbicide on the row), systems in which the fruit production and its quality are high.

For the varieties discussed, planted in super intensive orchards (2000 trees / ha), fruit load regulation is absolutely necessary when seeking large and quality productions which can be sold profitably as dessert fruit.

Five varieties of apples, less widespread in Romania, but widely spread in the European Community countries, were studied in terms of many particularities of trees development, of productivity and fruit quality. These varieties are: Rajka, Rubinola, Topaz, Otava and Goldstar, and we can find them on SC. Delifood S.R.L. plantation from Urvind, Bihor county.

The plantation was founded in 1999, with tress grafted on M_9 rootstock. For the planting distances used 4 x 1.20 m, we got a density of 2083 trees/ha.

Key words: fruits, tree, variety, technology, tillage system, soil

INTRODUCTION

The main objective of the research was to determine the extent to which five new varieties of apple (Rajka, Rubinola, Topaz, Otava and Goldstar), are to be introduced and developed in EU, if the conditions are suitable for the natural environment of Aleşd – Urvind fruit-growing area as well as the artificial environment conditions represented by the four maintenance systems in the orchard soil (tilled bare fallow, bare fallow combined with herbicide on the rows of trees, grassing by bands between the rows and total grassing) frequently found in commercial orchards from the area.

To achieve this main objective, a series of secondary objectives were set and made, namely:

a. To determine the variability of total "extra" and first quality fruit production under the influence of soil maintenance systems in the orchard, for the five tested varieties.

b. To determine the variability of main productivity elements under the influence of soil maintenance systems in the orchard for the varieties studied.

c. To quantify the extent to which fruit production and productivity elements were influenced by the climatic conditions of experimental years (2006-2008) and by their interaction with the genotype and soil maintenance systems in the orchard.

MATERIAL AND METHOD

Five varieties of apples, less widespread in Romania, but widely spread in the European Community countries, were studied in terms of many particularities of trees development, of productivity and fruit quality. These varieties are: Rajka, Rubinola, Topaz, Otava and Goldstar, and we can find them on SC. Delifood S.R.L. plantation from Urvind, Bihor county.

The plantation was founded in 1999, with tress grafted on M_9 rootstock. For the planting distances used 4 x 1.20 m, we got a density of 2083 trees/ha.

The experiment was bifactorial and it included:

Factor A – ***soil maintenance systems,*** with graduations:

a_1 – classic bare fallow, with soil tillage on the whole surface of the orchard;

a_2 – bare fallow with herbicides on the tree rows;

a_3 – strip fallow between rows and tilled on the row of trees;

a_4 – occupied fallow of soil in the orchard.

Factor B – ***soil*** with graduations: b_1 Rajka; b_2 Rubinola; b_3 Topaz; b_4 Otava şi b_5 Goldstar.

This resulted in a number of 20 variants that were located by linear block method in three repetitions, each repetition comprising a total of 10 trees.

Breeding technology was standard one applied in intensive apple orchards, with changes made by the head of the farm according to the main destination of fruit production (industrialization).

In this paper we made the following measurements and observations:

1. Phenophases of fruit and vegetative organs.
2. Cross-sectional area of the trunk at 25 cm from the grafting point, annually by measuring the diameter with the calibre on direction of the line and perpendicular to the row and by applying the formula πR^2, expressed in cm^2.
3. Treetop volume by measuring the two diameters on direction of the line and perpendicular to the row, the trees' height and by applying the cone formula $1/3\ \pi R^2 \times h$, expressed in m^3.
4. Annual average growth of shoots by measuring all the shoots higher than 5 cm and dividing it to their number, expressed in cm.
5. Fruit production, by weighing the fruit from each tree. The production of repetition parcel was calculated by summing the production/tree only for 8 out of the 10 trees from the parcel (dismissing the neighbour's influence) and transforming it in t/ha.
6. Determinations regarding physical chemical characteristics of fruit such as: fruit size on 25 samples, measuring with the calibre the large diameter (D), small diameter (d) and height, then by applying the formula (D+d+h)/3 expressed in mm.

RESULTS AND DISCUSSIONS

Calculation and interpretation of experimental results were mainly done with the help of variance analysis applied to the series of polifactorial experience of type A x B x years. To establish the significance between the performances of the tested variants it was used the multiple comparisons test (Duncan, Tuckey), values $DS_{5\%}$ being calculated on the basis $s^2_{AxBxani}$ to be able to emphasize consistency over time of the analysed results. The model analysed was the one presented by Ardelean et al., 2002.

Heritability coefficients of some quantitative or interest traits, to differentiate the cultivars studied with respect to the extent to which they have used natural and artificial environment conditions (soil maintenance systems in the orchard) were calculated as the

ratio between genetic variance and total phenotypic variance ($H = \frac{s_G^2}{s_P^2}$), only partial data as a consequence of variance analysis.

To determine the total phenotypic variance of characters means analysed in the series of experiments A x B x years, we used the formula proposed by Allard, 1966.

Coefficients determination of simple (r_{xy}), partial ($r_{xy.z}$) and multiple ($R_{x.yz}$) correlation as well as the coefficient of linear regression b_{xy} and quadratic regression (c_{x^2y}) was made using the models presented by Ardelean, 2010.

Fruit production

Like most fruit species, apple production per unit area still remains the main criteria for evaluating the effectiveness of a breeding technology or hierarchy of some cultivars regarding their suitability to the respective technologies, in as various conditions as possible of the natural environment (Negrilă, 1964; Ghena et al., 1977; Cociu, 1977; Mitre et al., 2007; Ropan, 2000).

The results obtained in a series of experiments of type A x B x years, in Urvind, during 2006-2008, were predominately referred to fruit prodution per unit area and also how the various productivity elements have answered to the action of the analysed experimental factors, on one hand, and to the interaction between these factors and the conditions of experimental years, on the other hand.

Data analysis presented in table 1 highlights the fact that both varieties and soil maintenance systems have significantly influenced production performance (t/ha) registred in our research.

Among varieties, Topaz and Rubinola stand out as very productive, which record total fruit production of 26.2 t/ha (Topaz) and 25.7 t/ha (Rubinola), on average, during three years and the four soil maintenance systems. The least productive proved to be Goldstar (21.5 t / ha) and Otava (21.6 t / ha), while Rajka variety can be considered medium productive with (23,6 t/ha) in Urvind conditions from Bihor county.

Table 1

Soil and soil tillage system influence on the production of fruit (t/ha) in the series of bifactorial research A x B x years type (Urvind, 2006 -2008)

Cultivar / ***Tillage system***	**Rajka**		**Rubinola**		**Topaz**		**Otava**		**Goldstar**		**Mean of tillage system**	
Bare fallow	27.4	a	26.1	C	27.0	a	24.9	d	24.6	D	26.0	A
Bare fallow+herbicides	25.7	c	26.2	B	26.2	b	24.3	d	22.8	Ef	25.0	A
Strip fallow	22.6	f	24.4	D	23.5	e	21.3	g	20.6	G	22.5	B
Occupied fallow	18.8	i	17.5	J	19.0	h	15.9	k	18.0	Ij	17.8	C
Mean of cultivar	23.6	N	25.7	M	26.2	M	21.6	P	21.5	P		

$DS/SD_{5\%}$ for two means of A = 2.4 – 2.6 t/ha

$DS/SD_{5\%}$ for two means of B = 1.5 – 1.7 t/ha

$DS/SD_{5\%}$ for two means A × B = 0.8 – 0.9 t/ha

N.B. The difference between any two values, followed by at least a common letter, is not significant

Regarding the effect of maintenance systems on fruit production, data from the last column of Table 1.place first the bare fallow (25.0-26.0 t/ha) followed by the soil tillage

system only on the tree line (22.5 t/ha). Note that the difference between the two systems is significant allowing us to observe high economic efficiency of the bare fallow, no matter if it is "classic" or row of trees with herbicide.

"EXTRA" and first quality fruit production

The results obtained in the series of experiments of type A x B x years, in Urvind during 2006-2008, referred not only to the total fruit production per unit area but also how the extra and first quality fruit production has been influenced by the action of analyzed experimental factors on the one hand, and the interaction between these factors and experimental years conditions, on the other hand.

The results presented in Table 2. point out that both varieties and soil maintenance systems have significantly influenced the production of "extra" and first quality fruit registered in the research..

Among varieties, Topaz and Rubinola stand out as very valuable, according to the analysed character, on average during three years, on the four soil maintenance systems, which record extra and first quality fruit production of 19,4 – 18,9 t/ha, representing 72,1% - 74,4% from the total fruit production. Less valuable proved to be (13,8 t/ha) and Otava (14,0 t/ha), while Rajka variety can be considered medium valuable with (15,5 t/ha) with regard to "extra" and first quality fruit production.

Table 2

Soil and soil tillage system influence on the production of fruit (t/ha) Extra and first quality, in the series of bifactorial research A x B x years type (Urvind, 2006 -2008)

Cultivar / ***Tillage system***	**Rajka**	**Rubinola**	**Topaz**	**Otava**	**Goldstar**	**Mean of tillage system**
Bare fallow	22.1 a	20.8 B	21.4 ab	19.9 c	19.6 cd	20.7 A
Bare fallow+herbicides	19.4 cd	18.9 D	19.0 d	17.5 e	16.4 f	18.3 B
Strip fallow	12.2 h	13.2 G	12.4 h	11.8 hi	11.2 i	12.2 C
Occupied fallow	8.1 j	7.9 j	8.1 jk	6.9 k	7.8 j	7.8 D
Mean of cultivar	15.5 N	19.4 M	18.9 M	14.0 NP	13.8 P	

$DS/SD_{5\%}$ for two means of A = 1.5 – 1.7 t/ha;
$DS/SD_{5\%}$ for two means of B = 1.6 – 1.8 t/ha;
$DS/SD_{5\%}$ for two means A × B = 0.8 – 0.9 t/ha;
N.B. The difference between any two values, followed by at least a common letter, is not significant

Regarding the effect of soil maintenance systems on the "extra" and first quality fruit production, the data from the last column of table 2. place first bare fallow (20.7 t/ha) followed, very closed, by the other three soil maintenance systems tested. Note that the difference between the last three systems is significant which raises serious questions about the suitability of orchards completely unreclaimed (non-organic) for commercial production of high quality fruit, i.e. the apple.

Analysis of genotype x system maintenance interaction effect (G x S) shows that it has highly visible consequences on the differentiation of 20 experimental variations. The biggest fruit production of "extra" and first qualities has been the variety Rajka (22.1 t/ha) on bare fallow, soil maintenance system in the orchard, with the significant differences from all other variants. At small but significant differences, we have fall Topaz and Rubinola varieties, both on bare fallow and also bare fallow with herbicide on the tree row (19.0 t/ha). The smallest production of "extra" and first fruit quality has been obtained in

the unreclaimed (occupied fallow) system over the entire orchard, all varieties and especially the variety Otava for which this type of production (6.9 t/ha) was significantly inferior to all the rest of the experimental variants tested.

Variability of productivity elements

Like most pome fruit species, for the apple, the elements of productivity (number of fruit / tree, fruit weight, fruit-sectional area, annual length of branches, productivity index) are regulated by genetic, physiological and technological factors. Among physiological factors, a decisive role has the number of fruits after fertilization and intensity of physiological drop and among technological factors, the first place is fructification cutting and standardizing the load of fruit by fruit thinning (chemically or manually).

Phenotypic expression of productivity elements is decisive to achieve total production of fruit per unit area (Cociu et. al., 1997), that is why we consider it necessary to see to what extent experimental factors and their graduations have influenced the phenotypic manifestation of these characters. Variability of characters that form the productivity elements for the apple, highlighted in a series of bifactorial experiences type A × B × years in Urvind is presented in table 3. To save space, we resorted to presenting only the interaction effects of the two experimental factors (soil maintenance system in the orchard and cultivar) on the variability of productivity elements, as for the most part of these characters, the effects of each experimental factor in part were significant only between the soil tillage systems and rarely between cultivation.

Data analysis from the first column of Table 3 allow us to state that interactions between graduations of the two experimental factors have produced the greatest variability in the number of fruit/tree, the limits of this variability were 37.5 and 66.8 fruit/trees. Varieties Rajka and Rubinola, on bare fallow, tillage system in the orchard, recorded the highest number of fruits harvested/tree (63.1 - 66.8), at significant differences of any combination between the graduations of two experimental factors. Topaz, Otava and Rubinola varieties are practically identical in their response to the various systems of maintenance of soil in the orchard, but at big and significant differences as compared to the Rajka and Rubinola.

The lowest numbers of fruit / tree were recorded in all varieties, strip fallow system, with significant differences between four of the five varieties tested. Only between Rajka and Goldstar, the difference in the number of fruit / tree is significant, suggesting that, in terms of the character, the two genotypes have different capacities to adapt to less favorable growing conditions offered by the occupied fallow system in the orchard.

The data presented for this element of productivity allow us to conclude that the new apple varieties tested, widely used at EU level, show obvious differences in terms of their response to soil maintenance system, expressed by the number of fruit/tree. Rajka and Rubinola are placed on top based on this character when they are grown in classic bare fallow system or with herbicides on the tree row.

Data table 3. also show that, new varieties of apple inclusively, widespread in the EU, the variability of average fruit weight is quite big (140.7 to 205.2 g), it was significantly influenced both by each of the two experimental factors considered in this study and by the interaction between them (data in the second column of the table). Cultivars studied behaved quite uniformly on the four soil maintenance systems, between varieties Rajka, Rubinola, Topaz and Goldstar there is practically no significant difference with respect to average fruit weight (176.5 to 186.4 g).

An exception is Otava fruit variety for which the average fruit weight (152.2 g) is significantly smaller than the other four varieties, irrespective of the maintenance of soil in the orchard.

Table 3.

Influence of variety and soil tillage system on the elements of productivity in the series of bifactorial experiments type A x B x years (Urvind 2006-2008)

No. of var.	Name of variant	No. of fruit/tree	Fruit weight G	Trunk section cm^2	Annual branches length (cm)	Index of productivity kg/cm^2
1	Bare fallow /Rajka	66.8 a	205.2 a	38.3 a	39.8 a	0.43 a
2	Bare fallow /Rubinola	63.1 a	192.9 b	39.5 a	34.6 bc	0.42 ab
3	Bare fallow /Topaz	51.1 bcd	164.1 de	39.5 a	28.0 efg	0.42 ab
4	Bare fallow /Otava	50.0 bcd	162.7 de	33.0 bcd	38.8 ab	0.40 ab
5	Bare fallow /Goldstar	55.1 b	187.5 b	29.0 fgh	41.1 a	0.40 ab
6	Bare fallow + herbicides/Rajka	55.3 b	185.0 b	35.2 bc	38.1 c	0.38 abc
7	Bare fallow + herbicides/Rubinola	52.7 bc	186.4 b	35.6 b	37.1 b	0.37 abc
8	Bare fallow + herbicides/Topaz	48.7 bcd	157.1 cd	33.9 bcd	26.9 efgh	0.36 abc
9	Bare fallow + herbicides/Otava	47.5 cd	147.5 gh	33.0 efg	31.3 cde	0.36 abc
10	Bare fallow + herbicides/Goldstar	42.5 de	175.6 bc	27.0 hi	31.3 cde	0.36 abc
11	Strip fallow/Rajka	51.2 bcd	168.4 de	32.3 cde	33.5 f	0.35 abc
12	Strip fallow /Rubinola	46.2 cde	162.3 de	32.7 cde	32.4 cd	0.34 abc
13	Strip fallow /Topaz	44.9 de	140.7 h	32.0 def	24.4 hj	0.33 bc
14	Strip fallow /Otava	46.2 cde	150.7 fg	32.5 cde	28.9 ef	0.33 bc
15	Strip fallow /Goldstar	37.5 e	173.2 c	24.7 ij	30.0 de	0.32 cd
16	Occupied fallow /Rajka	48.2 cd	167.9 cd	32.1 def	28.2 i	0.32 cd
17	Occupied fallow /Rubinola	42.9 de	164.3 de	29.1 fgh	27.3 efgh	0.32 cd
18	Occupied fallow /Topaz	44.4 de	141.5 gh	28.1 gh	22.0 i	0.30cd
19	Occupied fallow /Otava	45.6 cde	147.8 gh	25.7 i	25.7 hi	0.29 cd
20	Occupied fallow /Goldstar	39.4 e	169.6 cd	22.7 j	25.6 ghi	0.29 cd
$DS_{5\%}$ for two means AxB =		2.7 – 3.2	7.3 – 8.7	2.7 – 3.2	3.6 – 4.3	09-0.1

N.B. The difference between any two values, followed by at least a common letter, is not significant

Data presented in the second column of Table 3 highlight the fact that the interaction cultivar x maintenance system has produced the greatest variability in the average fruit weight. Obviously, Rajka variety has the biggest fruit when is grown on bare fallow (205.2 g), at significant differences compared to all other combinations of the experimental factors. At the opposite pole there are varieties Topaz and Otava, cultivated on strip fallow and occupied fallow systems (140.7 to 147.8 g).

A special comment must be made to Otava variety, which even in the conditions of the bare fallow with herbicides on the row, has average weight of small fruit, equal to those grown on the occupied fallow system. This is further proof that, at least for this variety, average fruit weight is strongly fixed in the hereditary basis and less influenced by the interaction with the natural and technological conditions. In terms of this character, variety Otava is less adapted to Urvind conditions.

The experimental results presented in table 4 reveal the fact that between cultivation and soil maintenance systems in the orchard there are significant differences in terms of trunk sectional area.

Table 4

Effect of cultivar and tillage system on the area of trunk cross section in the series of experiments type A × B × Y (Urvind, 2006 -2008)

Cultivar / ***Tillage system***	**Rajka**	**Rubinola**	**Topaz**	**Ottava**	**Goldstar**	**Mean of tillage system**
Bare fallow	38.3 a	39.5 a	39.5 a	33.0 bcd	29.0 fgh	35.8 A
Bare fallow+herbicides	35.2 bc	35.6 b	33.9 bcd	30.0 efg	27.0 hi	32.3 B
Turf strips	32.3 cde	32.7 cde	32.0 def	32.5 cde	24.7 ij	30.8 B
Turf	32.1 def	29.1 fgh	28.1 gh	25.7 i	22.7 j	27.5 C
Mean of cultivar	34.5 MN	35.2 M	35.6 M	30.3 N	25.8 P	

$DS/SD_{5\%}$ pentru două medii A/*for two means of A* = 3,1 – 3,4 cm^2
$DS/SD_{5\%}$ pentru două medii B/*for two means of B* = 3,3 – 3,7 cm^2
$DS/SD_{5\%}$ pentru două medii AxB/*for two means A × B* = 2,7 – 3,2 cm^2
The differrence between any two values, followed by at least a common letter, is not significant

Varieties are grouped, with respect to this character, at two opposites: with large surface of trunk section (34.5 to 35.6 cm^2) for Rajka, Rubinola and Topaz varieties, and the small surface of the trunk section (25, 8 to 30.3 cm^2), for Otava and Goldstar varieties, the differences between the two breeding groups are statistically ensured.

The greatest variability of trunk sectional area was recorded for the interaction of cultivar x maintenance system, as shown in the analysis results presented in table 4., the limits of this variability ranging between 39.5 and 22.7 cm^2. Rubinola, Topaz and Rajka varieties, on classic bare fallow, have the largest area of the trunk section (38.3 to 39.5 cm^2) the differences between these three varieties are insignificant. However, differences between these three varieties on bare fallow and all other combinations cultivar x maintenance system are statistically ensured which reveals the respective cultivars as well as the bare fallow as the soil maintenance system in intensive orchards, able to provide good vegetative growth of trees. Otava and Goldstar varieties are at the opposite end of the scale, with medium and small surfaces of the trunk section, especially when the occupied fallow system was used.

Based on the above considerations, we believe that it is appropriate to detail the broad heritability coefficient (H) for fruit production and productivity elements, including the trunk section area. This ratio will show exactly what proportion of these features is due to hereditary basis of genotypes (cultivars) respectively, natural and artificial environmental conditions offered them.

Table 5

The coefficients of heritability (H) of production and productivity elements in the series of experiments variety x maintenance system x years (Urvind, 2006-2008)

Character	**H**	***Environment***		
		Total	**Natural**	**Artificial**
***Fruit production* t/ha**	0,37	0,63	0,16	0,47
No. of fruits/tree	0,40	0,60	0,33	0,27
***Fruit weight* (g)**	0,33	0,67	0,29	0,38
***Area of trunk section* (cm^2)**	0,44	0,56	0,27	0,29

A detailed analysis of the data from Table 5 allows us to state that for the five apple varieties tested on different soil maintenance systems, genotype contribution to the achievement of fruit production and productivity index is low to medium (between 0.35 to 0.45). Environmental contribution is represented by much higher values (0.56 to 0.67) but out of these, the artificial environment, represented by maintenance systems, has the largest share, for all the characters,

A special observation is also worth for the average weight of fruit and tree trunk section area to which the contributions of the natural and the artificial environment are significantly closer. On the other hand it is worth noting that on the case of the number of fruit / tree, the contribution of the natural environment seems to be the most important, very close to the value of genotype effect on this character. Conversely, in the case of total fruit production (t/ha), the effects of artificial environment (soil maintenance systems) are three times higher than those of the natural environment and also significantly higher than those of genotype (cultivar).

Productivity index, expressed in kg fruit/cm^2 of trunk, section was considered for a long time, with regard to the apple, a true indicator of production capacity of a cultivar, or of a technological ring applied on soil or trees. More recent work (Mitre, 2007; Flachowsky et al., 2011) reveal that the above statement was and remains valid only for classic and semi-intensive apple orchards. The new, modern varieties, with reduced strength for growth and grafted on weak rootstocks, using much higher planting densities (2000 - 3000 trees / ha) which makes the connection between trunk sectional area and fruit production (productivity index) to occur exclusively during the first 4-6 years of the life of the tree, during which it reaches almost to full fruition capacity (Hank Magda et al., 2007).

The results we obtained in our research in Urvind, during 2006-2008, regarding the variability of the productivity index (kg/cm^2), for the five varieties of apple grown on four soil maintenance systems in the orchard, are presented in the last column of table 3. It is obvious the lack to differentiate the separate effects of the two experimental factors as well as their interaction effects. Basically, real significant differences between all varieties are recorded only in the bare fallow system and respectively the occupied fallow system of the orchard. This is another proof that the new apple varieties, grafted on rootstocks of poor and very poor vigour and planted at high density (2000 trees/ha), productivity index has only a relative value, only for orientation especially in the in the early years of normal fruition of trees.

CONCLUSION

- All five new varieties of apple (Rajka, Rubinola, Topaz, Otava and Goldstar), tested in the research, find in the respective basin favourable pedoclimatic

growing conditions. Their share, in the new plantations, will have to be chosen carefully according to the main objective pursued, namely:

- when total fruit production /ha is most important, then the biggest share should have Topaz and Rubinola varieties;
- when the fruit production for dessert ("Extra" and first qualities), Goldstar, Rubinola and Topaz, Otava and Rajka varieties will be preferred, instead of Otava and Rajka varieties;
- for fruit destined to specific industrialization (dried apples, compote, jam etc.) Goldstar variety is recommended, with the highest value of the sugar /acidity ratio.

- All new varieties prefer bare fallow (classic or with herbicide on the row), systems in which the fruit production and its quality are high. A special note for Goldstar variety which, in terms of total bands of green grass (strip fallow) or occupied fallow of the orchard, gave big quantities of "Extra" and first fruit production qualities with a sweet taste.
- For the varieties discussed, planted in super intensive orchards (2000 trees / ha), fruit load regulation is absolutely necessary when seeking large and quality productions which can be sold profitably as dessert fruit. Thus:
  - in orchards maintained on bare fallow (classic or with herbicides on the tree row), a number of 50-65 fruit / tree will be assured, in which case fruit dimension and their weight will be between 170 – 200 g;
  - in orchards with soil tillage on the tree row and strip fallow, the number of fruit / tree should not exceed values of 50 – 55, because for a bigger number of fruit / trees, their average weight will decrease significantly;
  - in occupied fallow orchards, the optimal number of fruit/tree will be maintained at levels of 40 – 50, thus there are chances that the average weight of fruit will be between 175 – 200 g, that allow the classification to extra or first category fruit or desert.

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