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不同钾镁配比对‘早酥’梨果实品质的影响

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摘 要：【目的】研究不同钾镁配比对‘早酥’梨果实糖酸组分、矿质元素含量的影响，旨在为梨生产中钾镁肥料的合理施用和果实品质提升提供依据。**【方法】**以7 a(年)生‘早酥’梨为试材，设置6个钾镁配比处理：0，2.69，5.38，8.07，10.76，16.14，21.52，分别于花后15 d和60 d 2次施入。**【结果】**钾镁配比对果实中钾钙镁含量影响不同，随钾镁配比的升高，果实中钾含量先增加后减少，钙镁含量先减少后增加，钾镁配比为5.38时钾含量最高；不同钾镁配比对‘早酥’梨果实可溶性固形物含量有显著影响，呈先增加后减少的趋势，果实中可溶性固形物含量与果实中镁含量呈极显著负相关；随着钾镁配比的升高，有机酸含量呈逐渐增长趋势，处理间有机酸含量呈极显著差异，钾镁配比为10.76时，可溶性固形物含量、固酸比、糖酸比最高；‘早酥’梨果实中果糖含量最高，占总糖含量的52.52%，为果糖积累型，山梨醇、蔗糖随钾镁配比的升高呈先增加后减少的趋势；‘早酥’梨果实中有机酸以柠檬酸和苹果酸为主，柠檬酸与钾镁配比成负相关，奎尼酸与莽草酸呈极显著正相关。‘早酥’梨为柠檬酸优势型。**【结论】**钾镁配施改善了‘早酥’梨果实中糖酸品质，当钾镁配比为5.38~10.76时，果实的品质最好，因此生产中建议使用的钾镁配比为5.38~10.76。

关键词：‘早酥’梨；钾镁配比；糖酸组分；矿质含量
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Effect of potassium-magnesium ratio on ‘Zaosu’ pear fruit quality

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Abstract: 【Objective】Potassium (K) and magnesium (Mg) are essential macro nutrients for plants. Excessive K in plants has an antagonistic effect on Mg uptake, particularly when Mg is low in soils. Despite the well-known role of Mg in various critical functions, there is surprisingly little research about the role of Mg nutrition in fruit crop production and quality. Hence, Mg is often considered a “forgotten element”. However, Mg deficiency is increasingly becoming an important limiting factor in intensive fruit crop production systems, especially in soils fertilized with high K. Research has shown that reasonable combination of potassium and magnesium had a positive effect on the yield and quality of vegetable and fruit crops. The effects of different potassium-magnesium ratio on sugars, acids and mineral elements in ‘Zaosu’ pear fruit were studied in order to provide reference for applying potassium and magnesium fertilizers to produce high quality fruit. 【Methods】Field experiment was performed in a pear orchard located in Xingcheng city, Liaoning province, China, during 2018 to 2019. Seven-year-old ‘Zaosu’ pear trees at a distance of 4m between rows and under standard horticultural practices and disease and pest control were selected. Each treatment consisted of 3 biological replicates each consisting of two-tree plot. Six treatments were set with different potassium-magnesium ratios including 0, 2.69,

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5.38, 10.76, 16.14 and 21.52. The potassium and magnesium fertilizers were applied to the soil at 20 cm under the base of each tree at 15 days and 60 days after full blooming. During the harvest season (August 20, 2019), twenty fruit in the outer canopy were randomly collected. All the samples were washed and air dried. Some of fruit were used to determine the quality traits including contents of soluble solids, soluble sugars and total organic acids, sugar components and acid components. Solid/acid ratio and sugar/acid ratio were calculated. The remaining fruit samples were dried at 75-80 ℃ for determinations of potassium, calcium and magnesium using an inductive coupled plasma emission spectrometer (iCAP 6200).【Results】The potassium-magnesium (K/Mg) ratio had significant effects on the contents of potassium, calcium and magnesium in fruit. With the increase in K/Mg ratio, the content of potassium in fruit first increased and then decreased, and the contents of calcium and magnesium first decreased and then increased. When the K/Mg ratio was 10.76, the potassium content in fruit was the highest while the contents of calcium and magnesium were the lowest, and therefore the ratios of K/Mg and K/Ca in the fruit were the highest. There was an extremely significant difference between the treatment with a K/Mg ratio of 10.76 and that with a K/Mg ratio of 0. K/Mg ratio had a significant effect on soluble solids in pear fruit and was significantly positively correlated with total acid content; the nitrogen content in the fruit was significantly negatively correlated with the sugar/acid ratio; the potassium content in the fruit was strongly positively correlated with the soluble sugar content in the fruit (R=0.970); the magnesium content in the fruit was significantly negatively related to soluble solids. The K/Mg ratio in the fruit was significantly positively correlated with the content of soluble solids. The soluble solid content, the solid/acid ratio and the sugar/acid ratio were the highest under the treatment with the K/Mg ratio of 10.76. The sweetness index and flavor index increased as the K/Mg ratio in fertilization increased from 5.38 to 10.76, but not significantly. The content of fructose in‘Zaosu’pear fruit was the highest, accounting for 52.52% of the total sugar content. Sorbitol and sucrose increased first and then decreased with the increase in K/Mg ratio. Citric acid and malic acid were the main organic acids in‘Zaosu’pear fruit. Citric acid was negatively correlated with K/Mg ratio in fruit, and quinic acid had an extremely significant positive correlation with shikimic acid.【Conclusion】The quality related to sugars and acids in‘Zaosu’pear fruit was improved by combined application of potassium and magnesium fertilizers. Lower K/Mg ratio increased the fruit flavor indexes, solids/acid ratio and sugar/acid ratio. When K/Mg ratio was 5.38-10.76, fruit quality was the best. Therefore, this K/Mg ratio range is recommended for fertilization in‘Zaosu’pear production.

Key words:‘Zaosu’pear; Potassium and magnesium ratio; Sugar and acid components; Mineral contents

钾和镁是植物生长必需的营养元素。钾元素被称为“品质元素”[1]，是果实生长发育中关键的营养元素，参与多种酶的活化，与蔗糖合成相关酶的活化密切相关[2]，是维持细胞生长和细胞膨压的重要渗透调节物质[3-4]，参与源库器官之间同化物的转运[5-6]；与其他大、中量营养元素的研究相比，镁元素营养机理的研究相对较少，至少近10年来镁的重要性被科学家低估。镁被称为“被遗忘的元素”[7]，镁是植物生长必不可少的中量元素，是叶绿素的组成部分，在ATP参与的反应中起重要作用[8]。镁还是多种磷酸酶组成成分，有促进磷酸化的作用[9]，也是多种酶的活化剂，参与多种化学反应[10]。果树对钾的吸收具有奢侈吸收的特性，过量供应不直接表现出中毒症状，但会抑制树体对镁的吸收，引起树体养分不平衡，出现镁缺乏症[11]，不仅影响树体生长发育，限制产量，而且影响果实品质，常表现出各种生理失调症状。

前人研究表明钾镁合理配施对于果实品质的提升具有积极作用。在含钾营养液中加入50~80 mg·L^{-1}的镁元素能提高果实产量与品质，而且与单施氯化钾相比，氯化镁与氯化钾1∶4配施后可明显改善番茄果实内在品质和外观[12]。施镁有提高茶多酚的作

用，钾和镁的共同施用可以提高乌龙茶的风味[13]。李国良等[14]在香蕉上的研究发现，低钾条件下配施镁肥可以提高香蕉可溶性固形物和可溶性糖含量，而在高钾条件下配施镁肥，可溶性固形物和可溶性糖含量稍有降低。求盈盈等[15]研究结果表明，单株施镁肥0.2 kg+钾肥0.5 kg可显著提高杨梅果实可溶性固形物含量、糖酸比、维生素C含量，果实中钾、铁、钙含量显著提高。钾镁元素对果实品质的重要意义已得到证实，但是研究多集中在大田作物[16-20]、蔬菜作物[21-22]，在果树香蕉[14]、杨梅[15]、葡萄[23]和柚[24]有部分研究，但钾镁元素配施对‘早酥’梨果实品质的影响未见报道。因此，本试验以‘早酥’梨为试材，研究不同的钾镁配比对‘早酥’梨果实糖酸组分和矿质元素含量的影响，旨在为梨生产中钾镁元素的合理施用和果实品质提升提供依据。

1　材料和方法

1.1　材料

本试验于2018—2019年在中国农业科学院果树研究所砬山试验基地梨示范园进行。土壤基础数据如表1所示。试验选用7 a（年）生乔砧密植‘早酥’梨，株行距为1 m×4 m，树形为圆柱形。选取生长势与产量相近的树体，每个处理为6株树，2株为1个小区，每处理3次重复，采用常规统一管理方式。

表1　土壤基础数据

Table 1　Soil basic data

土壤深度 Soil depth/cm	*w*（有机质） Organic matter content/%	*w*（碱解氮） Alkali-hydrolyzale nitrogen content/(mg·kg-1)	*w*（速效磷） Available P content/(mg·kg-1)	*w*（速效钾） Available K content/(mg·kg-1)	*w*（速效镁） Available Mg content/（mg·kg-1）	*w*（有效钙） Available Ca content/(mg·g-1)
10~20	1.888	122.362	12.950	174.670	55.221	1.034
20~40	1.080	67.530	2.327	85.864	56.078	1.312

钾镁肥施用量参考武晓[25]和马晓丽[26]的方法，钾肥为硫酸钾，镁肥为七水合硫酸镁；钾镁配比计算公式为K∶Mg=硫酸钾中钾的摩尔质量分数施肥量∶七水硫酸镁中镁的质量分数施肥量。试验处理如表2所示，条沟施肥，分别于花后15 d和60 d 2次施入。8月20日果实成熟期采集果实样品，从每株树的东南西北4个方位树冠外围采集无病虫害、果面洁净的果实20个，立即运回实验室。选一部分做果实糖酸组分测定，一部分做果实矿质元素含量测定。

表2　实验处理

Table 2　Experimental treatments

处理 Treatment	钾镁配比 Potassium magnesium ratio	硫酸钾 K_2SO_4/（g per plant）	硫酸镁 $MgSO_4$/ (g per plant)	尿素CO $(NH_2)_2$/ (g per plant)	磷酸二铵 $(NH_4)_2HPO_4$/ (g per plant)
1	0.00	0	256	299.6	178.6
2	2.69	150	256	299.6	178.6
3	5.38	300	256	299.6	178.6
4	10.76	600	256	299.6	178.6
5	16.14	900	256	299.6	178.6
6	21.52	1 200	256	299.6	178.6

1.2　测定方法

1.2.1　*糖酸组分测定方法*　采用日本产PAL-1型折光仪测定可溶性固形物含量，采用蒽酮-比色法测定可溶性糖含量；采用氢氧化钠法用全自动电位滴定仪（905型，瑞士万通公司）测定总酸含量，果实糖酸组分的测定参考郑丽静[27]方法，糖组分用离子色谱仪（ICS-5000，美国戴安公司）测定；酸组分用型液相色谱仪（LC-10A，日本岛津公司）测定。

1.2.2　*矿物质元素测定方法*　将果实洗净切片，105 ℃杀青0.5 h，75 ℃烘干至恒重，粉碎后用80目筛过筛后自封袋保存。取3.000 g样品加5 mL硫酸和少量去离子水过夜，第2天逐次加H_2O_2，用消煮炉在220 ℃消煮至澄清透明，过滤至50 mL试管中，用电感耦合等离子体发射光谱仪（iCAP 6200，英国赛默飞世尔科技公司）测矿质元素含量。

1.3　统计方法与分析

数据采用SPSS 25数据分析软件进行方差、相关性分析，用Microsoft Excel 2019进行数据处理与统计分析。

固酸比=可溶性固形物含量/总酸含量。

糖酸比=可溶性总糖含量/总酸含量。

糖组分的甜度值不同，根据姚改芳等[28]的方法设蔗糖、果糖、葡萄糖和山梨醇甜度值分别为1、1.75、0.7和0.4，因此甜味指数=蔗糖×1+果糖×1.75+葡萄糖×0.7+山梨醇×0.4。

风味指数[29]=甜味指数/总酸含量。

2 结果与分析

2.1 钾镁配比对'早酥'梨果实矿质元素含量的影响

如图1所示，钾镁配比对果实中氮、磷、钾、钙、镁含量的影响存在差异，果实中氮含量随钾镁配比的升高呈先增加后减少之后增加的趋势，钾镁配比为21.52时，果实中氮含量最高；钾镁配比对果实中磷含量无显著影响；果实中钾含量随钾镁配比的升高呈先增加后减少的趋势，钾镁配比为10.76时钾含量最高；钙、镁含量的变化趋势与钾含量变化趋势相反，随钾镁配比的升高，钙、镁含量先减少后增加；钾含量变化与钙、镁含量变化呈负相关。钾镁配比为10.76时，果实中钾含量比处理1高9.47%，钙含量比处理1低41.97%，镁含量比处理1低28.71%。当钾镁配比在5.38~10.76时，果实中钾含量降低而钙、镁含量升高。

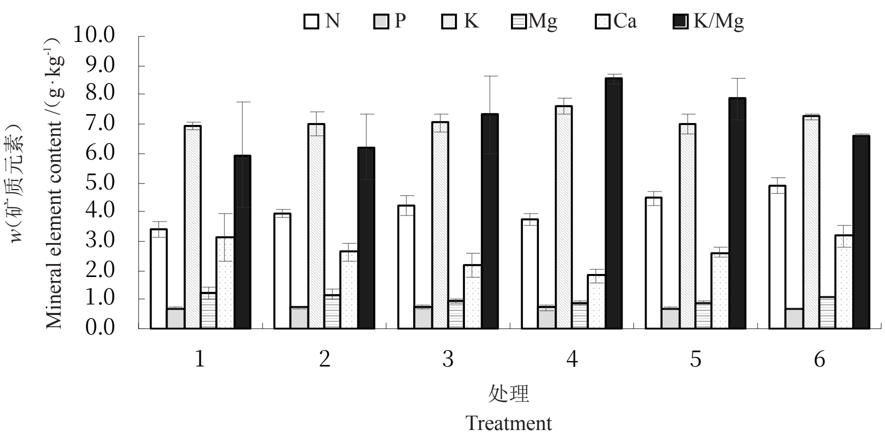

图1 钾镁配比对'早酥'梨果实矿质元素含量的影响

Fig. 1 Effect of K/Mg ratio on mineral elements in 'Zaosu' pear fruit

2.2 钾镁配比对'早酥'梨果实品质的影响

由表3可知，随着钾镁配比的升高，果实中的可溶性固形物含量呈先增加后减少的趋势，钾镁配比10.76时可溶性固形物和可溶性糖含量最高，分别比处理1高12.86%和16.9%。可溶性糖含量变化在0.05水平上无显著差异。随钾镁配比的增加，总酸含量显著增加。固酸比和糖酸比是评价果实品质的重要指标，钾镁配比为10.76时固酸比和糖酸比最高，品质最好。从表4可以看出，处理与总酸呈显著正相关；果实中氮含量与糖酸比呈显著负相关，果实中钾含量与果实中可溶性糖含量呈极显著正相关，R=0.970，果实中镁含量与可溶性固形物含量呈显著负相关。果实中钾镁比与可溶性固形物含量呈显著正相关。

2.3 钾镁配比对'早酥'梨糖组分的影响

如表5所示，山梨醇和蔗糖的变化趋势相似，随钾镁配比的升高呈先增加后减少的趋势；'早酥'梨糖组分中果糖占比最高，达到52.52%，山梨醇次之，为18.69%，葡萄糖为15.39%，蔗糖最低，为13.40%，

表3 钾镁配比对'早酥'梨果实品质的影响

Table 3 Effect of K/Mg ratio on the quality of 'Zaosu' pear fruit

处理 Treatment	w(可溶性固形物) Soluble solids content/%	w(可溶性糖) Soluble sugar content/(mg·g^{-1})	w(总酸) Total acid content/(mg·g^{-1})	固酸比 Solids acid ratio	糖酸比 Sugar acid ratio
1	12.05±0.093 c	6.775±0.085 a	1.74±0.02 d	68.103±0.67 a	38.936±0.488 a
2	12.215±0.184 c	6.668±0.329 a	1.87±0.01 c	64.706±0.846 b	35.66±1.764 ab
3	12.30±0.139 c	6.913±0.649 a	1.93±0.01 ab	65.485±0.767 b	35.867±3.366 ab
4	13.636±0.133 a	7.918±0.031 a	1.96±0.01 b	68.972±0.540 a	40.317±0.157 a
5	13.493±0.104 a	6.925±0.277 a	1.89±0.03 bc	68.262±0.528 a	36.336±0.89 ab
6	12.967±0.139 b	7.130±0.576 a	2.11±0.07 a	61.381±0.656 c	31.089±1.006 b

注：不同小写字母表示在 α = 0.05 水平上差异显著。下同。

Note: Different small letters indicate significant difference at α = 0.05. The same below.

表 4　‘早酥’梨果实矿质含量与果实品质相关性

Table 4　Correlations between mineral contents and fruit quality traits of ‘Zaosu’ pear fruit

	处理 Treatment	N	P	K	Mg	Ca	钾镁比 K/Mg	可溶性固形物 Soluble solids	可溶性糖 Soluble sugar	总酸 Total acid	固酸比 Solids acid ratio	糖酸比 Sugar acid ratio
处理 Treatment	1.000											
N	0.777	1.000										
P	-0.284	-0.149	1.000									
K	0.451	-0.120	-0.071	1.000								
Mg	-0.578	-0.157	-0.317	-0.535	1.000							
Ca	-0.021	0.348	-0.694	-0.569	0.746	1.000						
钾镁比 K/Mg	0.505	-0.013	0.262	0.668	-0.975**	-0.800	1.000					
可溶性固形物 Soluble solids	0.758	0.222	-0.178	0.693	-0.821*	-0.417	0.849*	1.000				
可溶性糖 Soluble sugar	0.421	-0.203	-0.093	0，.970**	-0.631	-0.621	0.765	0.744	1.000			
总酸 Total acid	0.855*	0.725	-0.120	0.559	-0.364	-0.076	0.317	0.486	0.443	1.000		
固酸比 Solids acid ratio	-0.361	-0.727	0.122	0.107	-0.383	-0.481	0.479	0.279	0.294	-0.654	1.000	
糖酸比 Sugar acid ratio	-0.549	-0.916*	0.193	0.225	-0.215	-0.545	0.363	0.106	0.368	-0.66	0.928**	1.000

注：*在 $p < 0.05$ 水平时差异显著，**在 $p < 0.01$ 水平时差异显著。

Note: Values followed by *and ** mean significant correlation at $p < 0.05$ and $p < 0.01$.

表 5　钾镁配比对‘早酥’梨糖组分的影响

Table 5　Effect of K/Mg ratio on ‘Zaosu’ pear sugar components

处理 Treatment	w(山梨醇) Sorbitol content/ (mg·g^{-1})	w(葡萄糖) Glucose content/ (mg·g^{-1})	w(果糖) Sucrose content/ (mg·g^{-1})	w(蔗糖) Sucrose content/ (mg·g^{-1})	甜味指数 Index of sweet taste	风味指数 Index of flavor
1	19.40±0.30 c	16.65±0.05 a	54.60±0.40 a	12.000±0.00 d	126.96±0.62 b	79.613±0.367 a
2	17.00±0.00 d	15.95±0.05 c	53.75±0.05 a	9.900±0.20 e	121.93±0.25 c	71.471±0.893 ab
3	21.95±0.05 a	15.05±0.05 e	51.50±0.10 b	20.880±0.10 a	130.24±0.29 a	73.592±0.177 ab
4	21.30±0.10 b	15.60±0.10 d	53.65±0.25 a	18.345±0.25 b	131.78±0.30 a	72.215±0.985 ab
5	16.90±0.10 d	14.30±0.00 f	53.85±0.35 a	12.600±0.10 c	123.61±0.47 c	65.638±0.806 b
6	17.05±0.15 d	15.95±0.15 b	51.80±0.30 b	7.700±0.10 f	116.34±0.79 d	53.409±0.806 c

因此‘早酥’梨为果糖积累型；甜味指数是根据甜度比例计算所得，果糖的甜度最高，山梨醇的甜度最低；风味指数为甜味指数与总酸之比。钾镁配比为5.38时，果糖含量最低但山梨醇与蔗糖含量最高。钾镁配比为5.38、10.76时，甜味指数和风味指数较高，但差异不显著。

2.4　钾镁配比对‘早酥’梨酸组分的影响

如表6所示，‘早酥’梨酸组分中柠檬酸占比最高，为48.49%，苹果酸次之，为30.95%，奎尼酸占比为16.04%，莽草酸为4.50%，富马酸最低，为0.02%。由苹果酸与柠檬酸的比值小于1可知，‘早酥’梨为柠檬酸优势型。处理间苹果酸和柠檬酸含量呈显著差异，随钾镁配比的增加，苹果酸先增加后减少，柠檬酸含量的变化趋势与苹果酸完全相反。钾镁配比为2.69时，奎尼酸与莽草酸含量最低。

3　讨　论

土壤中低浓度和高浓度的钾都会抑制植株对钙镁的吸收[30-31]。低钾胁迫下叶片、叶柄和果梗中镁含量显著高于高钾胁迫下的含量[32]，植物对低钾胁迫与高钾胁迫的响应不同。谌琛[33]研究表明，与对照相比，施用钾肥显著降低了果实中钙、镁含量，提高了果实中氮、钾含量。本研究在‘早酥’梨果实中得到了相似的验证，低钾镁配比下果实中镁和钙含量高于高钾镁配比下镁和钙含量，但是高钾镁比在16.14~21.52时，果实中镁和钙含量略有提高，沈涛[34]在甜柿上研究表明高钾处理促进了果实中钾镁元素的吸收，增加了果实中钾镁元素含量。

表6　钾镁配比对‘早酥’梨酸组分的影响

Table 6　Effect of K/Mg ratio on ‘Zaosu’ pear acid components

处理 Treatment	*w*(奎尼酸) Quinic acid content/(mg·g-1)	*w*(苹果酸) Malic acid content/(mg·g-1)	*w*(莽草酸) Shikimic acid content/(mg·g-1)	*w*(柠檬酸) Citric acid content/(mg·g-1)	*w*(富马酸) Fumaric acid content/(mg·g-1)
1	0.656±0.018 a	0.926±0.024 b	0.155 5±0.0025 a	1.672 0±0.0345 b	0.000 55±0.000 05 d
2	0.402±0.049 c	0.937±0.047 b	0.135 5±0.0005 d	1.512 5±0.0345 c	0.000 9±0.000 00 b
3	0.588±0.009 ab	1.169±0.018 a	0.148 5±0.0015 b	1.151 5±0.0345 e	0.000 8±0.000 00 c
4	0.455±0.103 bc	1.223±0.040 a	0.142 5±0.0005 c	1.707 5±0.0075 b	0.001 0±0.000 00 a
5	0.488 5±0.012 bc	0.927±0.058 b	0.144 0±0.0010 bc	1.437 0±0.0020 d	0.000 8±0.000 00 c
6	0.582±0.039 abc	0.798 5±0.077 b	0.146 5±0.0005 bc	1.899 5±0.0055 a	0.000 4±0.000 00 e

果实中的糖酸组分及比例是衡量果实品质和风味的重要指标。前人研究结果显示，可溶性固形物含量表明果实的成熟度、营养成分含量以及甜度[35]；钾肥能够提高苹果[36-37]、沙田柚[38]、梨[39]、葡萄[40]果实中可溶性固形物和可溶性糖含量。钾促进了果实中糖的合成，配施镁肥果实中可溶性糖含量比对照增加20.8%[41]，钾镁配施比单独施用钾肥和镁肥显著提高果实中可溶性固形物和可溶性糖含量[31,42-43]。本研究与前人的研究结果一致，与单施镁肥相比，钾镁配比为10.76时，可溶性固形物和可溶性糖含量分别提高了13.2%和16.9%。固酸比通常被用作指示糖酸平衡的指标，高固酸比表明果汁的口感更好[28,43]，钾镁配比为10.76时，固酸比和糖酸比最高，‘早酥’梨的口感更好。由姚改芳等[28]对早熟梨糖组分的测定分析可知，‘早酥’梨的果糖含量显著高于‘雪青’与‘七月酥’，本试验中适量钾镁配比显著提高了蔗糖含量，配比为5.38时蔗糖含量比单施镁肥高73.3%，蔗糖含量最高，果糖含量显著降低，蔗糖含量达到极显著水平，这与张弦[44]在苹果上的研究结果一致；钾镁配比为21.52时，山梨醇与蔗糖含量降低了12.3%和35.8%，高钾镁配比显著降低了蔗糖含量。Shen 等[32]的研究表明，成熟期果实中的山梨醇、蔗糖和总糖浓度随钾的供应而显著升高，钾对果糖含量没有影响。这与蔗糖转运蛋白（SUT）和山梨醇转运蛋白（SOT）基因表达上调密切相关。多个糖相关基因的表达促进了营养物质从源到库的转运，增加果实中糖的积累。单施镁肥的固酸比、糖酸比和风味指数较高，原因是总酸的含量较低，使得固酸比、糖酸比和风味指数的比值较高。因此，低钾镁配比即钾缺乏配施适宜镁肥，可以改善果实的风味。

姚改芳等[45]、高海燕等[46]对梨有机酸组分的研究中，白梨总酸含量较低，以苹果酸与柠檬酸的比值确定类型，‘早酥’梨为柠檬酸型。与对照相比，钾元素显著提高了有机酸含量[32]，钾元素对有机酸影响的研究结果各有不同，张雯[36]研究表明钾元素显著降低了苹果中总酸含量，唐岩等[37]指出，钾元素与苹果中总酸含量无显著关系。沙守峰[47]研究表明，施用钾肥增加了‘新苹梨’总酸、柠檬酸、苹果酸含量；本试验数据表明钾镁配比与总酸含量为极显著相关，且随钾镁配比的升高，总酸含量呈显著增加趋势。可能是施钾肥果实中Cyt-ACO（细胞质乌头酸酶）活性显著增加，NAD-MDH（NAD-苹果酸脱氢酶）活性显著降低所致。钾镁元素对‘早酥’梨酸组分的影响还有待进一步研究。

果实中矿质元素含量与果实品质有密切关系。谌琛[33]对苹果的研究显示，果实中钾含量与果实的可溶性固形物、总酸、可溶性糖含量呈正相关；马晓丽[26]研究表明，葡萄果实中的钾钙镁含量与果实的可溶性固形物含量呈显著正相关，而与总酸含量呈显著负相关；张涓涓等[24]研究表明，马家柚中可溶性固形物含量与果实中钾、镁含量呈负相关，总酸含量与果实中钾含量呈负相关，与钙、镁含量呈正相关。本试验研究结果表明，果实中可溶性固形物含量与果实中钙、镁含量呈负相关，与镁含量呈极显著负相关，与果实中钾含量呈正相关，与钾镁比呈极显著正相关。果实中总酸含量与果实中钾含量呈正相关，与镁含量呈负相关。果实可溶性固形物、总酸、可溶性糖含量与果实中钾钙镁含量的相关性众说纷纭，因树种、采收期、果实中矿质元素含量变化，以及果实品质参数而异。

4　结　论

合理钾镁配施可改善早酥梨品质，‘早酥’梨的

钾镁配比在5.38~10.76时，果实的品质最好，因此在生产中建议钾镁配施适宜比例为5.38~10.76。

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