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葡萄钾营养及其在果实中积累的研究进展

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摘 要:钾是植物营养的关键性元素,对酶的活化、植物生长、光合作用、渗透势调节、同化产物的运输、产量与品质均有重要作用。目前,在葡萄生产上,钾是需求量最多的营养因子,但存在钾肥施用量不足、利用率不高等问题。钾作为葡萄植株中含量最丰富的阳离子,占植株干物质总量的0.4%~4.3%。葡萄果实作为强大的钾库,在果实转色后对钾的积累逐渐增多,到果实完全成熟时钾离子含量占阳离子总含量的70%左右,其中果皮中钾含量最高,种子次之,果肉最少。钾离子在果实中的转运是通过离子通道来实现的,在葡萄果实中,同时存在KUP/KT/HAK和Shaker两大基因家族,共同调控钾在果实的运输与再转运。同时,土壤条件、气候因素、品种特性、激素水平、栽培措施等都对果实中钾的积累有重要影响。综述了葡萄的钾营养、葡萄果实中钾的积累过程及其影响因素,为更好地调控果实中的养分平衡和指导生产提供依据。

关键词:葡萄;钾;营养;果实;积累

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Research advances on potassium nutrition and berry accumulation in grapevines

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Abstract: Potassium is essential for vine growth, enzyme activation, photosynthesis, osmotic regulation, yield and quality. Potassium is one of the most abundant cations in grapes, the potassium ion concentration in cytoplasm can reach 100-200 mmol·L^{-1}, even up to 500 mmol·L^{-1} in apoplast. Potassium as a highly mobile element, can easily transfer from old tissue to a young area, and primarily concentrate in the center of the active part, such as the growing point, buds, berries and so on. Grape berries are a strong sink for K, and the potassium content has been rising in the whole growth period. Plant nutrient analysis results show that: more K is accumulated particularly during ripening. In the mature period, the potassium ion can account for about 70% of the total cation content and 66% of the total potassium content of above-ground organs. Among berry tissues, K concentration per unit fresh weight is higher in the skin than in the fleshy pericarp. The K concentration in the seeds is lower than in the skin but slightly higher than in the flesh. K concentration in the skin is 1.7-6.9 times higher than that in the pulp and 1.6-4.3 times higher than in the seeds. The concentration in the skin can reach 50% of the whole berry potassium concentration. Potassium transportation is done by ion channels. There are low affinity K^+ absorption systems and high affinity K^+ absorption systems in higher plants on the absorption of potassium, the former done in external high K^+ concentration and the latter in low K^+ concentration. In grapes, potassium ion channels belong to the Shaker gene families, and *VvKUP 1* and *VvKUP 2* are two genes encoding potassium transport carriers and are found in larger expressions before veraison and lower expressions after veraison. The ex-

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pression of these carriers is restricted to the skin, the tissue in the berry with the highest K concentrations. Researches on the other types of K^+ transport mechanisms in different berry tissues may better help in understanding the mechanism of berry K accumulation. Potassium movement occurs in both xylem and phloem. In grape berries, the xylem seems to be a minor route of K entry because xylem flow into the berry may be low due to the low transpiration rate of the berry. Potassium is the major cation in the leaf xylem sap and shoot xylem sap. While K concentration differs significantly with leaf age, leaf xylem sap flow is highest in the middle leaves and lowest in the old and young leaves. At the beginning of grape growth, potassium reflux occurs in the plant through the xylem, and remobilization of K from other organs to the berries can be reabsorbed into the phloem by apoplast. Between the veraison and mature period, the K^+ concentration being gradually reduced in the different organs shows that potassium is being retransported into the berries. Many factors may affect K accumulation in berries including soil, climate, variety, phytohormones and cultural practice. K deficiency may be induced in saline conditions where Na^+ is the predominant cation. Gravel soil is better for absorption of the potassium than sand and clay; high temperature, and shading treatment promotes the potassium accumulation in fruit; varieties differ on the potassium absorption efficiency, while higher efficiency is found in 'Cabernet Sauvignon' than in 'Cabernet Franc'. Cultivation measures affect the potassium distribution and accumulation in berries. Canopy management is a technique that results in the altered position and density of leaves, shoots, and fruit to achieve a specific desired arrangement. Reasonable leaf canopy management helps to decrease excessive potassium accumulation in the pulp, and reduces the pH of the wine. Crop load affects berry K accumulation by changing the balance of the source/sink for K. It may also have indirect effects on berry K accumulation through changes in the degree of shading in the canopy, availability of assimilates and rates of berry growth. The effects of the K addition on berry K accumulation are variable, with more K being accumulated when more fertilizers are applied. Results from other studies indicate that berry, juice, or wine K is not a positive correlation to potassic fertilizer supplement. There are data suggesting that increased irrigation tends to increase berry K accumulation. Berry and wine K concentrations were higher for irrigated treatments than for non-irrigated treatments. Irrigation enhances the dissolution of K from clay particles and its movement in the soil solution, which facilitates its supply to roots and provides higher uptake. Potassium accumulation in berries is a very complicated process. Comprehension of berry K accumulation requires an understanding of the function of K in the berries, how berry K requirements are determined, and how K is translocated into and out of the berry, while the available information is still unknown and limited. This review summarizes the potassium nutrition from the distributions, functions of potassium, potassium characteristics and uptake in grape, emphasis on the berry accumulation and relative impact factors, to better provide the basis for regulating nutritional balance in grape berries and producing scientifically.

Key words: Grapevines; Potassium; Nutrition; Berry; Accumulation

钾是植物营养的关键性元素，对植物生长、光合作用、同化产物运输、产量与品质均有重要的作用。钾作为大量元素，在农业生产中需求较多。但由于土壤中钾易被固定或可利用率低，加上销售市场钾肥价格偏高，广大种植户在施用钾肥时存在少施或不施的现象，使得作物生长得不到满足，缺钾现象普遍存在[1]。

葡萄作为钾质植物，每生产1 000 kg果实需从土壤中吸收4.0~7.2 kg的氧化钾[2]。葡萄果实是重要的钾库，在整个生长过程中，果实的钾含量逐渐增加，在着色期至成熟期达到最大值。葡萄缺钾表现为叶片边缘黄化，严重时导致叶缘变烧焦状；果粒变小，着色不良，在果实成熟期缺钾会导致落果。但果实中过高的钾浓度会降低葡萄酒中游离酸的含量，