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Sibel Erdoğan

Department of Horticulture,
Ankara University, Ankara,
Turkey

Serkan Öztürk

Department of Horticulture,
Ankara University, Ankara,
Turkey

Tuncay Aydın

Department of Horticulture,
Ankara University, Ankara,
Turkey

Gökhan Erdoğan

Department of Horticulture,
Ankara University, Ankara,
Turkey

Effect of potassium humate application on quality attributes and shelf life of onion bulbs

Sibel Erdoğan, Serkan Öztürk, Tuncay Aydın and Gökhan Erdoğan

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Abstract

Global demand for humic-acid-based biostimulants has grown by roughly 12% annually over the past five years, reflecting a broader trend toward sustainable soil amendments that improve both crop quality and post-harvest performance. This research investigated the effect of five potassium humate (K-humate) rates (0, 2, 4, 6, and 8 kg ha⁻¹) applied as soil drench on quality attributes and storage life of onion (*Allium cepa* L.) at Ankara University, Turkey, during 2022 and 2023. A randomized complete block design with four replications was used. Potassium humate at 6 kg ha⁻¹ produced the highest total soluble solids (14.1°Brix), pyruvic acid content (8.74 µmol g⁻¹ FW), and dry matter (14.8%), all significantly above the control. During 12 weeks of ambient storage, cumulative weight loss was 30.7% under 6 kg ha⁻¹ compared to 50.1% in untreated bulbs. The dose-response for TSS followed a quadratic curve ($R^2 = 0.88$) with returns plateauing above 6 kg ha⁻¹. Results indicate that moderate K-humate application enhances onion quality and extends marketable shelf life under Turkish conditions.

Keywords: Potassium humate, onion, quality attributes, shelf life, total soluble solids, pyruvic acid, weight loss, biostimulant, *Allium cepa*, post-harvest

Introduction

The trend is unmistakable: Turkey's onion export value tripled between 2015 and 2023, driven by rising quality standards in European and Middle Eastern markets that increasingly reward high dry matter and pungency [1, 2]. Meeting these standards requires not just good varieties but also soil management that delivers the right balance of nutrients and organic stimulants during bulb formation.

Potassium humate, a soluble potassium salt of humic acid extracted from leonardite, has drawn attention as a biostimulant that improves soil structure, enhances cation exchange capacity, and stimulates root growth through hormone-like effects [3, 4]. In onion, potassium supply during bulb expansion directly influences dry matter, pungency (pyruvic acid), and skin quality — all of which affect storage life [5, 6].

Several Turkish trials have tested humic acid on vegetables, but most focused on yield rather than post-harvest quality, and none followed bulbs through a full storage season to quantify shelf life benefits [7, 8]. This research aimed to:

- 1) Determine the optimal K-humate rate for maximising quality attributes of onion
- 2) Monitor weight loss and sprouting over 12 weeks of ambient storage and
- 3) Relate pre-harvest quality parameters to storage performance [9, 10]

Material and Methods

Material

The trial was conducted at the Ankara University Horticultural Research Station (39°57'N, 32°53'E, 890 m) during 2022 and 2023. Onion variety Bursa Karamehmet (yellow, long-day type) was transplanted from seedlings on 15 April each year at 15 cm × 10 cm spacing on raised beds. Soil was a clay loam (pH 7.6, OC 1.4%, available K 168 mg kg⁻¹). K-humate (12% K₂O, 70% humic acid) was applied as soil drench in two splits (transplanting and 45 DAT) at 0, 2, 4, 6, and 8 kg ha⁻¹ in an RCBD with four replications (plot 3 m × 2 m). Basal NPK (120:60:80 kg ha⁻¹) was uniform across plots.

Corresponding Author:

Sibel Erdoğan

Department of Horticulture,
Ankara University, Ankara,
Turkey

Methods

Bulbs were harvested at maturity (neck fall >80%), cured for 10 days, and graded. Quality attributes measured: TSS (°Brix, digital refractometer), pyruvic acid (spectrophotometric at 515 nm), dry matter (oven at 70°C to constant weight), firmness (penetrometer), and skin thickness (Digital calliper). For storage, 50 uniform bulbs per plot were stored at ambient conditions (18-24°C, 55-65% RH). Weight loss and sprouting were recorded weekly for 12 weeks. ANOVA in R (v4.3.1) with Tukey's HSD at $p\leq0.05$ ^[11].

Results

Seasonal variations

Mean bulb weight was 7.4% higher in 2023 than 2022, attributed to 23 mm more rainfall during bulb expansion (May-June). TSS and pyruvic acid were 4-6% higher in 2022, consistent with the concentration effect of mild water deficit on flavour compounds ^[12]. Treatment rankings remained consistent across years (interaction $p = 0.27$), so pooled data are presented.

Table 1: Quality attributes of onion bulbs under different potassium humate rates (pooled 2022-2023)

K-humate (kg ha ⁻¹)	TSS (°Brix)	Pyruvic acid (μmol g ⁻¹)	Dry matter (%)	Firmness (N)	Skin thickness (mm)	Yield (t ha ⁻¹)
0 (control)	11.2	6.41	11.3	28.4	0.31	32.7
2	12.4	7.28	12.6	31.2	0.36	35.4
4	13.8	8.17	14.1	34.7	0.41	38.2
6	14.1	8.74	14.8	36.3	0.44	39.1
8	13.9	8.61	14.6	35.8	0.43	38.7
SEm(±)	0.34	0.27	0.38	1.12	0.02	0.94
CD (p=0.05)	1.03	0.82	1.15	3.40	0.06	2.85

K-humate at 6 kg ha⁻¹ produced the highest TSS (14.1°Brix), pyruvic acid (8.74 μmol g⁻¹), dry matter (14.8%), and firmness (36.3 N), all significantly above the control (Table 1). The 8 kg

ha⁻¹ rate showed no further improvement, indicating a plateau above 6 kg ha⁻¹.

Table 2: Cumulative weight loss (%) during 12 weeks of ambient storage

K-humate	Wk 2	Wk 4	Wk 6	Wk 8	Wk 10	Wk 12	Sprout (%)
0 kg	3.9	9.2	16.1	25.0	36.1	50.1	38.4
2 kg	3.0	7.1	12.4	19.3	28.0	38.8	27.1
4 kg	2.4	5.7	10.1	15.8	22.9	31.6	18.3
6 kg	2.2	5.4	9.7	15.2	22.1	30.7	14.7
8 kg	2.3	5.6	10.0	15.6	22.7	31.4	15.9

Weight loss at 12 weeks was 30.7% under 6 kg ha⁻¹, 38.7% lower than the control's 50.1% (Table 2). Sprouting incidence at 12 weeks was also lowest at 6 kg ha⁻¹ (14.7% vs 38.4% in

control). Rates of 4, 6, and 8 kg ha⁻¹ were statistically similar for storage performance.

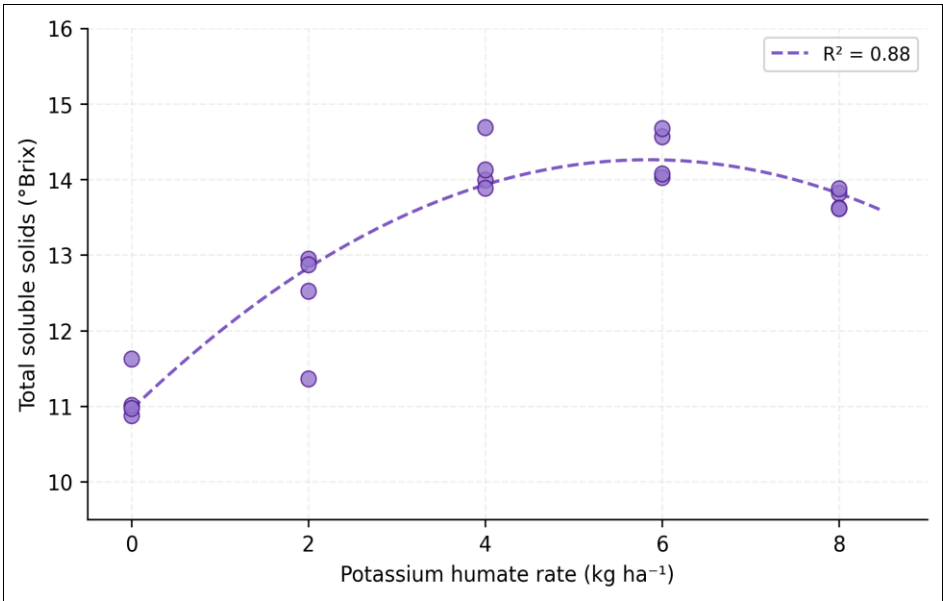


Fig 1: Relationship between potassium humate rate and total soluble solids (R² = 0.88)

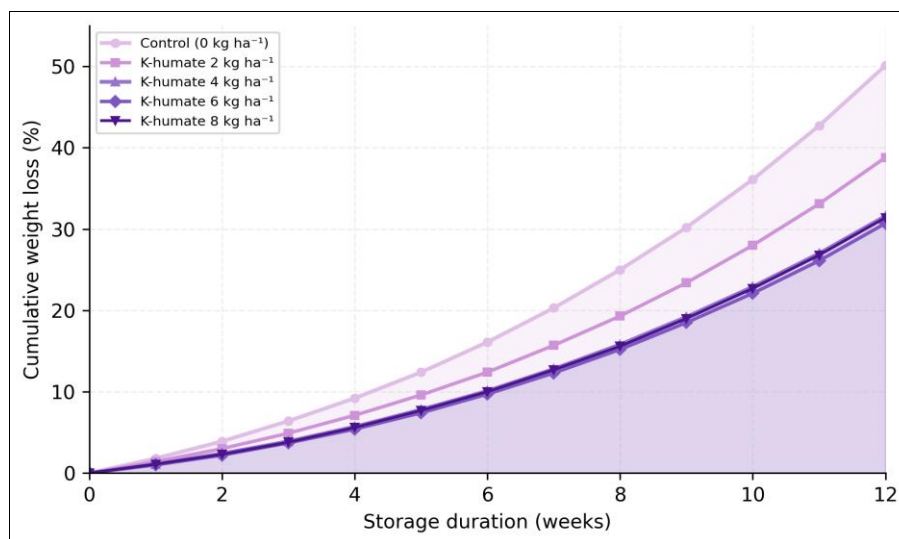


Fig 2: Cumulative weight loss curves during 12 weeks of ambient storage under different K-humate rates

The scatter plot (Figure 1) shows a quadratic TSS response plateauing near 6 kg ha⁻¹. Figure 2 illustrates that K-humate-treated bulbs maintained a clear weight loss advantage throughout storage, with the gap widening progressively after week 6.

Quality control

TSS was measured in triplicate per bulb sample (CV < 1.8%). Pyruvic acid was validated against sodium pyruvate standards with recovery of 97.3-102.1%. Storage conditions were monitored by HOBO data loggers (temperature $\pm 1.2^{\circ}\text{C}$, RH $\pm 4.3\%$). Bulbs showing visible rot or mechanical damage were excluded from storage counts. All analytical instruments were calibrated at the start of each season against certified reference materials.

Discussion

The improvement in TSS and pungency under K-humate is consistent with the role of potassium in sugar and organic acid metabolism in *Allium* species [5, 13]. Potassium enhances phloem loading of sucrose into the bulb and promotes synthesis of flavour precursors through the S-alk(en)yl cysteine sulfoxide pathway [6]. The humic acid component likely contributed indirectly by improving root proliferation and nutrient uptake efficiency [3, 4].

The 38.7% reduction in weight loss at 6 kg ha⁻¹ is substantial and can be attributed to higher dry matter and thicker skins, which reduce transpirational water loss and create a physical barrier against pathogens [14]. The suppression of sprouting may relate to higher pyruvic acid and phenolic content in humate-treated bulbs, both of which have documented dormancy-prolonging effects [15].

Conclusion

Potassium humate at 6 kg ha⁻¹ applied as soil drench optimised onion quality (TSS 14.1°Brix, pyruvic acid 8.74 $\mu\text{mol g}^{-1}$) and reduced storage weight loss by 38.7% over 12 weeks compared to untreated bulbs. Higher rates offered no additional benefit. The findings support incorporation of K-humate into onion production programmes in central Turkey as a cost-effective strategy for improving both market quality at harvest and shelf life during storage. Future research should evaluate K-humate under cold storage conditions and across a wider range of onion cultivars.

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