International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 916-919
Received: 04-07-2025
Accepted: 06-08-2025

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Effect of NPK levels on soil properties after the harvest of water spinach under central Telangana agro-climatic conditions

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9m.3876

Abstract
The present investigation entitled "Effect of NPK Levels on Soil Properties after the harvest of Water Spinach under Central Telangana Agro-climatic Conditions" was undertaken during 2024-2025 at the Post Graduate Institute, SKLTGHU, Mulugu, Siddipet District, Telangana. The study aimed to identify superior varieties and assess their interaction effects on soil physico chemical properties and nutrient availability after the harvest of water spinach. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with two factors, factor-I: varieties (Kashi Manu and CHWS-01) and factor- II: six NPK levels (F_1: 40:40:40, F_2: 60:40:40, F_3: 80:40:40, F_4: 60:60:60, F_5: 60:40:60, F_6: 80:40:60 kg/ha), comprising 12 treatment combinations replicated thrice. The results demonstrated notable variations between varieties and fertilizer levels. Kashi Manu (V_1) recorded higher values for soil pH (7.15), electrical conductivity (0.46 dS/m), available nitrogen (135.02 kg/ha), and available phosphorus (24.59 kg/ha). Conversely, CHWS-01 (V_2) excelled in available potassium (183.88 kg/ha). Among the fertilizer treatments, 60:60:60 NPK kg/ha (F_4) and 80:40:60 NPK kg/ha (F_6) resulted in the highest soil pH (7.16), 80:40:60 NPK kg/ha (F_6) records highest EC (0.66 dS/m), 40:40:40 NPK kg/ha (F_1) recorded highest available nitrogen (161.71 kg/ha), available potassium (197.2 kg/ha) and 60:40:40 NPK kg/ha (F_2) recorded maximum available phosphorus (26.47 kg/ha). Interaction effects revealed that (V_1F_4) and (V_1F_6) achieved the highest soil pH (7.18), (V_1F_6) showed maximum EC (0.67 dS/m). (V_1F_3) produced the highest available nitrogen (180.43 kg/ha) while V_1F_2 recorded the highest available phosphorus (32.32 kg/ha). The maximum available potassium (225.32 kg/ha) was obtained with (V_2F_1). Overall, the study demonstrated that varietal and NPK combinations significantly influence soil nutrient dynamics in water spinach, with CHWS-01 (V_2) coupled with appropriate NPK doses showing promising potential for nutrient use efficiency under central Telangana conditions.

Keywords: Water spinach, varieties, NPK levels, nutrient uptake and soil properties

Introduction

Water spinach, locally known as Karmatha bhaji (*Ipomoea aquatica* Forsk), is a semi-aquatic, herbaceous perennial crop belonging to the family Convolvulaceae. It is well adapted to marshy and waterlogged soils due to its short growth cycle. The plant is characterized by hollow, creeping or erect stems that often float, with adventitious roots developing at the nodes and anchoring into the soil (USDA, 2005) [23]. Originating from southern China, India, and the tropical to subtropical regions of Southeast Asia (Gothberg *et al*., 2005 and Chen *et al*., 1991) [10, 3], it is widely cultivated as a leafy vegetable owing to its nutritional importance. Water spinach is valued for its health-enhancing properties, being a rich source of dietary fiber, antioxidants, and essential nutrients (Hongfei *et al*., 2011; Gupta *et al*., 2005; Kala and Prakash, 2004; Faruq *et al*., 2002 and Ogle *et al*., 2001) [13, 11, 16, 6, 19]. Additionally, it has been shown to effectively utilize nitrogen from biodigester effluents to produce protein-rich edible biomass, highlighting its relevance in sustainable agricultural systems (Sophea and Preston, 2001) [21].

The growth, yield, and quality of plant species are largely influenced by soil properties, fertilizer management, and nutrient availability. Achieving higher yields and better quality requires maintaining favourable soil conditions (Chowdhury *et al*., 2008) [4].

Therefore, assessing crop performance under specific soil environments is essential for designing effective management practices that enhance productivity without compromising quality. Fertilizers act as important external inputs that enrich the soil nutrient pool and supply plants with essential minerals for proper growth. As highlighted by Chang *et al*. (2010) [2], plant morphological traits reflect the degree of mineral utilization within the system. Balanced application of NPK fertilizers improves root development, enhances nutrient availability, and promotes efficient absorption and accumulation of nutrients in plants (Fouda, 2016) [7]. Among the essential macronutrients, nitrogen (N), phosphorus (P), and potassium (K) are vital for plant growth. Nitrogen and phosphorus play a central role in the synthesis of proteins, nucleic acids, amino acids, vitamins, and other key biomolecules, while potassium regulates several physiological processes by activating enzymes, aiding assimilate translocation, and improving crop quality (El-Saady, 2016) [5].

While plants are capable of synthesizing essential organic compounds such as amino acids, lipids, and vitamins through photosynthesis, external supplementation with inorganic nutrients is still required to ensure balanced growth. In most cases, calcium, magnesium, and sulphur are sufficiently supplied by the soil and irrigation water, and thus are rarely emphasized in standard fertilization practices. Conversely, the application of NPK fertilizers is crucial for achieving optimal growth, yield, and quality in vegetable crops (Gianquinto *et al*., 2013) [9]. A deficiency or imbalance in NPK supply is a major constraint in vegetable cultivation, often leading to stunted growth, reduced productivity, and poor quality produce. However, over-application of these nutrients can result in toxicity, interfere with the uptake of other essential elements, diminish yields, escalate production costs, and negatively impact the environment. Spinach is particularly prone to nitrate accumulation because of its efficient uptake mechanism combined with limited capacity for nitrate reduction. Excessive nitrate content not only poses health risks to consumers but also contributes to environmental problems such as groundwater and surface water pollution through leaching and soil erosion (Zhang *et al*., 2012) [24].

Materials and Methods

The field experiment was conducted during the season *kharif,* 2024 at Post Graduate Institute for Horticultural Sciences, Sri Konda Laxman Telangana Horticultural University (SKLTGHU), Mulugu. The experiment with twelve treatments (Table 1) were laid out in Factorial Randomized Block Design (FRBD) in which, two varieties (Kashi Manu-V_1) & CHWS-01-V_2) were taken as factor-I and factor- II is six NPK levels (40:40:40-F_1, 60:40:40-F_2, 80:40:40-F_3, 60:60:60-F_4, 60:40:60-F_5, 80:40:60-F_6). The plot size is 3m x 2m and seeds are sown at a spacing of 30 x 20cm.

Table 1: Treatment details of the experiment

Treatment Code	Treatment Description
T_1	Kashi Manu with 40: 40: 40 kg each of nitrogen, phosphorus and potassium
T_2	Kashi Manu with 60: 40: 40 kg each of nitrogen, phosphorus and potassium
T_3	Kashi Manu with 80: 40: 40 kg each of nitrogen, phosphorus and potassium
T_4	Kashi Manu with 60: 60: 60 kg each of nitrogen, phosphorus and potassium
T_5	Kashi Manu with 60: 40: 60 kg each of nitrogen, phosphorus and potassium
T_6	Kashi Manu with 80: 40: 60 kg each of nitrogen, phosphorus and potassium
T_7	CHWS-01 with 40: 40: 40 kg each of nitrogen, phosphorus and potassium
T_8	CHWS-01 with 60: 40: 40 kg each of nitrogen, phosphorus and potassium
T_9	CHWS-01 with 80: 40: 40 kg each of nitrogen, phosphorus and potassium
T_{10}	CHWS-01 with 60: 60: 60 kg each of nitrogen, phosphorus and potassium
T_{11}	CHWS-01 with 60: 40: 60 kg each of nitrogen, phosphorus and potassium
T_{12}	CHWS-01 with 80: 40: 60 kg each of nitrogen, phosphorus and potassium

Soil analysis after harvest included estimation of pH, electrical conductivity (EC), available nitrogen, phosphorus, and potassium. The pH was determined in a 1:2.5 soil water suspension using a glass electrode pH meter, and EC was measured with a conductivity meter, expressed in dS/m (Jackson, 1973) [14]. Available nitrogen was estimated by the alkaline potassium permanganate method (Subbaiah and Asija, 1956) [22], while available phosphorus (kg/ha) was determined using Olsen's method (Olsen *et al*., 1954) [20], and available potassium (kg/ha) was measured by the flame photometer method (Hanway and Heidel, 1952) [12]. The initial physiochemical properties of the experimental soil before the study were: pH 7.1, EC 0.28 dS/m, available nitrogen 35.84 kg/ha, available phosphorus 20.16 kg/ha, and available potassium 91.84 kg/ha.

Results and Discussion

Soil properties

pH

The data on soil pH as affected by varieties, NPK levels, and their interactions are presented in Table 2. A significant varietal effect was observed, with Kashi Manu (V_1) recording a higher pH (7.15) compared to CHWS-01 (V_2). Soil pH was also notably influenced by NPK fertilization, where the highest values (7.16) were obtained with 60:60:60 NPK kg/ha (F_4) and 80:40:60 NPK kg/ha (F_6), which were statistically on par with 60:40:40 NPK kg/ha (F_2) (7.15) and 60:40:60 NPK kg/ha (F_5) (7.14). The lowest pH values (7.13) were recorded under 40:40:40 NPK kg/ha (F_1) and 80:40:40 NPK kg/ha (F_3). A significant interaction effect was also evident, with the combination of Kashi Manu with 60:60:60 NPK kg/ha (V_1F_4) showing the maximum soil pH (7.18), which was statistically comparable to Kashi Manu with 80:40:60 NPK kg/ha (V_1F_6) (7.18), whereas the minimum pH (7.12) was observed under the combination Kashi Manu with 80:40:40 NPK kg/ha (V_1F_3) and CHWS-01 with 40:40:40 NPK kg/ha (V_2F_1). These results are in line with the findings of Ganeshamurthy *et al*. (2015) [8], who reported that the optimum pH range for spinach and lettuce is 6.0-7.0. Similarly, Manisha *et al*. (2021) [18] reported in spinach that the highest soil pH (1:2) value of 7.48 was recorded with the recommended dose of fertilizers (RDF) along with 100% PSB, FYM, and boron, while the lowest pH (7.10) was recorded in the control. Comparable outcomes were also reported by John *et al*. (1999) [15].

Electrical Conductivity (dS/m)

The data on soil electrical conductivity (EC) as influenced by varieties, NPK levels, and their interactions are presented in Table 2. The effect of varieties on soil EC was found to be non-significant. However, EC was significantly influenced by NPK levels, with the highest value (0.66) recorded under 80:40:60 NPK kg/ha (F_6), while the lowest value (0.31) was observed with 40:40:40 NPK kg/ha (F_1). Significant interaction effects were also noted, where the combination Kashi Manu with 80:40:60 NPK kg/ha (V_1F_6) resulted in the highest EC (0.67), and the lowest EC (0.31) was obtained with combination of Kashi Manu with 40:40:40 NPK kg/ha (V_1F_1) and CHWS-01 with 40:40:40 NPK kg/ha (V_2F_1). These findings are consistent with Manisha *et al.* (2021) [18], who reported significant treatment effects on soil EC in spinach at harvest recorded maximum EC (0.49) in treatment with recommended dose of fertilizers (RDF) along with 100% PSB, FYM, and boron, whereas the minimum EC (0.34) was found in the control.

Available Nitrogen (kg/ha)

The results on available nitrogen (kg/ha) as affected by different varieties, NPK levels, and their interactions are shown in Table 2. The influence of varieties was significant, with Kashi Manu (V_1) recording the highest available nitrogen (135.02 kg/ha) compared to CHWS-01 (V_2). Among the NPK treatments, 40:40:40 NPK kg/ha (F_1) registered the maximum available nitrogen in the soil (161.71 kg/ha), which was statistically on par (158.48 kg/ha) with 80:40:40 NPK kg/ha (F_3), while the lowest value (98.06 kg/ha) was observed in 60:40:60 NPK kg/ha (F_5). A significant interaction effect was also evident, with the combination of Kashi Manu with 80:40:40 NPK kg/ha (V_1F_3) producing the highest available nitrogen content (180.43 kg/ha), closely followed by CHWS-01 with 40:40:40 NPK kg/ha (V_2F_1) (173.52 kg/ha), whereas the minimum nitrogen level (81.88 kg/ha) was noted in the combination of CHWS-01 with 80:40:60 NPK kg/ha (V_2F_6). Similar observations were made by Kumari and Tripathi (2018) [17], who reported that available nitrogen increased considerably with the application of urea, farmyard manure (FYM), or their combination. Likewise, Manisha *et al.* (2021) [18] in spinach found that nitrogen content at harvest was significantly influenced by treatments, with the highest level in RDF + 100% PSB + FYM + 50% B.

Available Phosphorus (kg/ha): The results on available phosphorus (kg/ha) as influenced by different varieties, NPK levels, and their interactions are presented in Table 2. Significant variation was observed between the varieties, with Kashi Manu (V_1) recording higher phosphorus availability (24.59 kg/ha) compared to CHWS-01 (V_2). Among the NPK treatments, 60:40:40 NPK kg/ha (F_2) registered the maximum phosphorus content in the soil (26.47 kg/ha), while the minimum (20.66 kg/ha) was recorded under 80:40:60 NPK kg/ha (F_6). A significant interaction effect was also evident, where the combination of Kashi Manu with 60:40:40 NPK kg/ha (V_1F_2) resulted in the highest soil phosphorus level (32.32 kg/ha), whereas the lowest value (19.27 kg/ha) was observed in the combination of CHWS-01 with 80:40:40 NPK kg/ha (V_2F_3). Similar results were documented by Manisha *et al.* (2021) [18] in spinach, where soil phosphorus availability was significantly influenced by different treatments. The control treatment recorded the lowest phosphorus content (16.63 kg/ha), while the highest level (23.34 kg/ha) was observed which received the recommended dose of fertilizers (RDF) along with 100% PSB, FYM, and boron, Findings further supported by Ali *et al.* (2013) [1].

Available Potassium (kg/ha)

The information on available potassium (kg/ha) as influenced by different varieties, NPK levels, and their interactions is presented in Table 2. The results revealed that soil potassium content was significantly affected by the varieties, with CHWS-01 (V_2) registering a higher value (183.88 kg/ha) compared to Kashi Manu (V_1). Among the NPK treatments, the highest potassium availability in the soil (197.2 kg/ha) was recorded under 40:40:40 NPK kg/ha (F_1), whereas the lowest (152.1 kg/ha) was observed with 80:40:60 NPK kg/ha (F_6). A significant interaction effect between varieties and NPK levels was also evident. The treatment combination CHWS-01 with 40:40:40 NPK kg/ha (V_2F_1) recorded the maximum available potassium (225.32 kg/ha), while the lowest was noted in combination of Kashi Manu with 80:40:40 NPK kg/ha (V_1F_3) with (132.77 kg/ha). Similar observations were made by Manisha *et al.* (2021) [18] in spinach, where available potassium content at harvest varied significantly across treatments. The maximum potassium level (241.77 kg/ha) was recorded in treatment with (RDF + 100% PSB + FYM + 100% B), while the minimum (224.56 kg/ha) was observed in the control treatment.

Table 2: Effect of varieties, NPK levels and their interaction on soil properties and nutrient content in water spinach

Treatments	Soil pH (1: 2.5) (Soil: Water)	Soil EC (1:2.5) (Soil: Water) (dS/m)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Factor I: Varieties (V)					
Kashi Manu (V_1)	7.15	0.46	135.02	24.59	157.96
CHWS-01 (V_2)	7.14	0.46	116.95	21.05	183.88
SEm±	0.004	0.002	1.44	0.26	1.48
CD (p=0.05)	0.012	NS	4.24	0.76	4.37
Factor II: NPK levels (F)					
F_1 (40:40:40)	7.13	0.31	161.71	21.87	197.20
F_2 (60:40:40)	7.15	0.36	118.28	26.47	174.01
F_3 (80: 40: 40)	7.13	0.47	158.48	22.43	159.45
F_4 (60:60:60)	7.16	0.39	118.03	22.12	170.79
F_5 (60:40:60)	7.14	0.57	98.06	23.38	171.95
F_6 (80:40:60)	7.16	0.66	101.34	20.66	152.10
SEm±	0.007	0.003	2.49	0.45	2.56
CD (p=0.05)	0.02	0.01	7.35	1.31	7.56
Interactions (V x F)					
V_1F_1	7.14	0.31	149.91	22.82	169.07
V_1F_2	7.14	0.37	133.15	32.32	161.88

V_1F_3	7.12	0.47	180.43	25.58	132.77
V_1F_4	7.18	0.39	125.56	22.75	143.87
V_1F_5	7.15	0.57	100.29	23.49	168.73
V_1F_6	7.18	0.67	120.80	20.58	171.40
V_2F_1	7.12	0.31	173.52	20.93	225.32
V_2F_2	7.16	0.36	103.41	20.62	186.13
V_2F_3	7.13	0.48	136.53	19.27	186.12
V_2F_4	7.14	0.40	110.51	21.48	197.72
V_2F_5	7.14	0.56	95.83	23.26	175.16
V_2F_6	7.13	0.65	81.88	20.75	132.81
SEm	0.01	0.004	3.52	0.63	3.62
CD (p=0.05)	0.03	0.01	10.39	1.86	10.69

Conclusion

The analysis of soil properties after harvest showed that nutrient availability was strongly affected by the interaction between varieties and fertilizer levels. The highest soil pH was recorded under combination Kashi Manu with 60:60:60 NPK kg/ha (V_1F_4), while maximum electrical conductivity was observed in 80:40:60 NPK kg/ha (F_6) and in combination of Kashi Manu with 80:40:60 NPK kg/ha (V_1F_6), reflecting the influence of elevated nitrogen application. Nitrogen content in the soil was highest in the combination Kashi Manu with 80:40:40 NPK kg/ha (V_1F_3), whereas phosphorus availability peaked in the combination of Kashi Manu with 60:40:40 NPK kg/ha (V_1F_2), indicating the effectiveness of moderate NPK application in maintaining soil fertility. Potassium levels were found to be highest in the combination of CHWS-01 with 40:40:40 NPK kg/ha (V_2F_1) and with 40:40:40 NPK kg/ha (F_1) alone also contributing significantly. Overall, the findings suggest that adopting suitable variety fertilizer combinations ensures better crop performance while preserving soil fertility after harvest.

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