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An efficient hydro-crop growth prediction system for nutrient analysis using machine learning algorithm

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ABSTRACT

The hydro nutrient management (HNM) for crop yield is effectively improved using proposed system. A hydro-crop growth prediction system (HCGPS) is designed using machine learning. The reconfigurable nutrients uptake crop yield prediction rate is enhanced. This proposed HCGPS is used to predict the crop yield by considering input parameters such as nutrient index (NI), electric conductivity limit (ECL), ion concentration factors (ICF) and dry weight of the crop and crop yield rate (CYR) to analyze the positive and negative correlation with crop growth. The proposed system is used to find correlation Index of input and output parameters to determine the prediction rate of crop yield. The proposed design improves smart prediction rate and efficiency of crop growth rate with optimal utilization of input variables. This proposed HCGPS is very helpful to achieve good quality yield with optimal utilization of input parameters.

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1. INTRODUCTION

Hydro nutrient management is a soilless technique to nurture yields in water. Such zero-soil farming way characterizes kind of an outstanding chance for the cultivation sphere, particularly in fields connecting with trials like uncontrollable soil deprivation and controlled water bases. Additionally, such farming practice proves outstanding consequences concerning an atmosphere and user responsive agriculture. It is similarly a consistent tool for the forthcoming trials in food security. Numerous areas of the world which face trials like volatile weather forms, extreme heat, condensed space obtainability, are captivating hydro nutrient management (HNM) as a substitute method to agriculture and a probable answer for such difficulties. The global marketable HNM business has increased four-five-fold in the preceding 10 years and is presently estimated amid 21k and 26k hectares with a farm gate value of US $5.9 to $7.9 billion. As a consequence, agriculture perceives are quickly shifting to smarter and accuracy agriculture observes for enhanced crop harvests and commercial gains. With the novel age of big data, approaches like machine learning (ML) and artificial intelligence (AI) available, data can be used to analyze, yield patterns and make forecasts [1], [2].

Depending on the above concerns investigators have advised and exasperated to overcome such breaches by uniting machine HNM agriculture can be mainly estranged to 3 types: nutrient film technique (NFT), Aquaponics and Deep Flow method. The NFT is 1 of the hydroponic ways such that a thin torrent of water having the compulsory dissolved nutrients otherwise known as NS is used that is an upright standard for development of the plant. This one is re-disseminated in the plants roots in the pipelines that are watertight, furthermore called otherwise as channels. In this scheme, NS is augmented with substances such as rock wool, sand that is conceded and re- disseminated inside a slope containing of plants positioned in a plastic furrow [3], [4].

This delivers the finest quantity of nutrients through its root system to the plant. HNM can also be called as a capable apparatus in the zones having restricted land assets. It bids main benefits upon the age-old soil farming and additional agriculture approaches. Low cost of installment, tranquil operation, supervision and actual utilization of nutrients and recycling of water are few of the motives that has made it a prevalent option [5].

The area of HNM is comparatively new and coalescing it with progressing tools and calculation can give cost and time effective resolutions. Few restrictions inside the zone of HNM contain the absence of: i) active supervision of nutrients castoff in the hydroponic harvests water; ii) comprehensive investigation and learning of factors which endorse quick development with decent quality harvests; and iii) relaxed and clever ways, wherein mechanization procedures by means of ML can aid us in forecasting education methods with HNM.

Diverse kinds of algorithms are castoff in order to project and forecast precise standards of the factors convoluted throughout the development procedure of the yields. This will improve the effectiveness and make HNM agriculture a relaxed and smart method to exploit yields. Hydroponic nutrient management is the practice of supplying plants with the necessary nutrients they need to grow in a hydroponic system. Hydroponics is a method of growing plants without soil, where plants are instead grown in a nutrient-rich water solution. Proper nutrient management is crucial for ensuring optimal plant growth, health, and productivity in hydroponic systems.

2. RELATED WORK

The research work [6], [7] explores the submission of fuzzy algorithm Mamdani technique to forecast the hydroponic watercress expansion. The idea in this effort is to utilize the fuzzy inference system (FIS) that is fundamentally a calculating system which functions on the fuzzy reasoning principle and a human reasoning similitude to forecast harvest development. Shan *et al.* [8] projected a scheme to assess the development of the plant by means of internet of things (IoT) and a logic of fuzzy to preserve finest water supply and levels of nutrients. The project is active when likened to the old-style approaches cast-off in HNM to assess the water and nutrient necessities throughout the lifespan of the plant. When we see research [9], neural networks which is artificial were pragmatic to a prototype which forecasts standards of electric conductivity (EC) and pH of the scheme. Such forecasts remain highly significant as they are needed by supplementary intellectual schemes which safeguard the correct and best process of the hydroponic system. This effort likewise attaches AI and ML with hydroponic systems that unlocks the technique to additional progression and education of clever systems in the arena of HNM which would lead to extra accurate farming [10].

3. PROPOSED HYDRO-CROP GROWTH PREDICTION SYSTEM

The planned system depicted in Figure 1, portrays the projected framework for forecast of complete crop yield rate (CYR) by means of ML [11]. The stages trailed are data congregation that comprises water sample investigation, which experiences the procedure of ion chromatography, to find ion concentrations. The results coming through the data congregation and analytics phases would be served to the ML algorithm to descend forecast consequences. The whole procedure is explained in three segments: design architecture, forecast system, flowchart of the scheme [12].

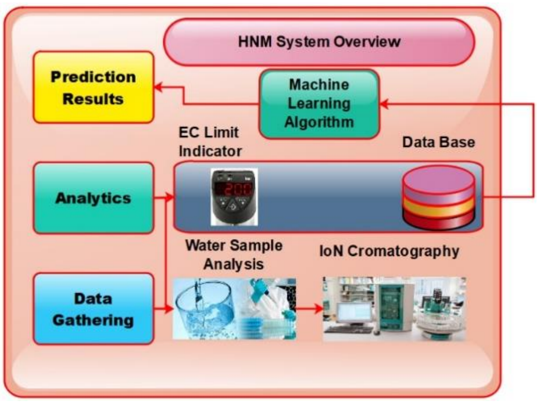

Figure 1. Fundamental block diagram of HNM system overview

3.1. System plan architecture

The whole arrangement is alienated into 3 chief portions: data fetching, analytics and forecast consequences. The scheme is not rigid and can be utilized for yields appropriate for NFT. The harvests of tomatos stayed cultured with a soilless NFT, a re-disseminated close scheme. Here, we deliberate samples of tap water for examination though rain or recycled water can also be utilized in NFT. The temperature least assessment was kept at 11.9 ˚C, and the temperature of ventilation was fixed to 19.9 ˚C. The nutrient solution (NS) resolution could be accepted premixed depending on magnitude necessities [13], [14]. Each two days, all cistern was replenished with renewed NS till the early volume. We also observe that the quantity of nutrients, filths or salts inside the water, is raised to the limit of EC. In order to preserve finest levels of EC, researchers fix the EC to the following points (5.1, 7.6 and 10.1 $dS\cdot m^{-1}$).

EC-dependent nutrient regulator for HNM harvest farming might deliver quantities of nutrients which are not in ideal quantities for the plants, hence cannot be cast-off unswervingly to find the ions concentration. A procedure of ion chromatography Dionex model DX500; was utilized to show the complete liquefied ion absorptions in the resolution [15], [16]. The info gave the standards for the ion concentration with in the several portions of the tomatos that is sectioned into the fruits, roots leaf, stem. A least temperature of 12.1 ˚C stood fixed and temperature of ventilation was 20.1 ˚C having a comparative humidity that remained continuously upper than 50.1%, excluding for two days, where it touched 44.1%. Once in 15 days, lone plant from every trial field was engaged for research. The density of the plant was witnessed to be 3.31 plants m^{-2}.

The parameters that were checked comprised complete plants dry matter weight along with EC limit, NI ingestion, total CYR complete Nitrogen content of fruits and leaves, the ion absorptions for each organ remained alienated as per their origin. Such particulars are utilized for the numerical data examination and the highly correlated parameters shall be nourished into the ML algorithm to forecast a yield for the goal parameter. Meanwhile the information is analyzed at every phase, it would assist in computing the elements concentration hooked on to the NI and the plants composition of minerals on an everyday scenario [17], [18].

3.2. The dataset comprises

The whole dry matter load of the tomatos and dry weights of the dissimilar portions ingesting. NS fresh plant, NI added plant and finally the NI remaining of the plant which is absent through the cycle and towards the conclusion of it was measured, endorsement of inorganic cations, specifically magnesium (Mg), sodium (Na), potassium (K), calcium (Ca) split for the different portions and is shown in gm $L^{-1}d^{-1}$.

3.3. Proposed prediction model

The prediction share of the scheme design is dependent on the ground of utilizing ML methods to assess the complete plants CYR, 'xx' days forward in stint. The prototype targets to forecast the complete CYR yield dependent over factors like: plants dry weight matter, NI, ion approvals of the fruit models prior and subsequent yield, EC limit and whole nitrogen factor of the fruit. Overall CYR of the harvest could be computed by the agreed formula [19].

$$\textit{Proposed}\text{ crop yield rate} = \frac{X_2 - X_1}{\tau_2 - \tau_1} \tag{1}$$

where X_1 and X_2 is represents dry weights of the tomatos in grams with respect to the τ_1 and τ_2 days. Year wise total crop yield prediction (C_f)=$\sum_{i=0}^{12} X_i^A - X_i^P$. Where X_i^A is represented the actual crop yield with respect to month wise, X_i^P is described as the prediction crop yield with respect to month wise and *i* is identified as number of months. Five-year total crop yield prediction (C_{ff})=$\sum_{j=0}^{5} C_{fj}^A - C_{fj}^p$. Where C_{fj}^A is represented the five wise actual crop yield, C_{fj}^p is described the five wise prediction crop yield and *j* represented the number years. Year wise total fertilizer utilization input parameters (F_u)=$\sum_{i=0}^{12} Ca_i^A + Mg_i^A + K_i^A + Na_i^A - Ca_i^P - Mg_i^P - K_i^P - Na_i^P$. Where Ca_i^A is represented the year wise actual calcium ion, Mg_i^A is described as the year wise actual magnesium ion, K_i^A is identified as actual potassium ion, Na_i^A is described as the year wise actual sodium ion, Ca_i^P is represented the year wise prediction calcium ion, Mg_i^P is described as the year wise prediction magnesium ion, K_i^P is identified as prediction potassium ion and Na_i^P is described as the year wise prediction sodium ion. Five-year wise fertilizer utilization $F_{uf} = \sum_{j=0}^{5} F_u^A - F_u^P$. Where F_u^A is described the five wise actual fertilizer utilization and F_u^P is identified as the five wise predicted fertilizer utilization.

3.4. System flowchart

The below phases define the method in more aspect and are revealed in Figure 2.

Phase 1: Gathering water trials for examination.

Phase 2: Setup and alteration system factors as per (tomatos) harvest needs EC limit range led lights range 410-710 nm and NI injection.

Phase 3: In order to find ion concentration, ion chromatography is utilized.
Phase 4: Gathering for the analysis of nutrient data by enchanting input parameters such as ion concentration, EC limit, NI, nitrogen content and complete plants dry weights.
Phase 5: Computation of the complete crop development ratio by means of (1).
Phase 6: Relationship amid input parameters and target parameter absolute CYR.
Phase 7: Submission of ML algorithm on the dataset of the parameters given.
Phase 8: Forecast consequences.

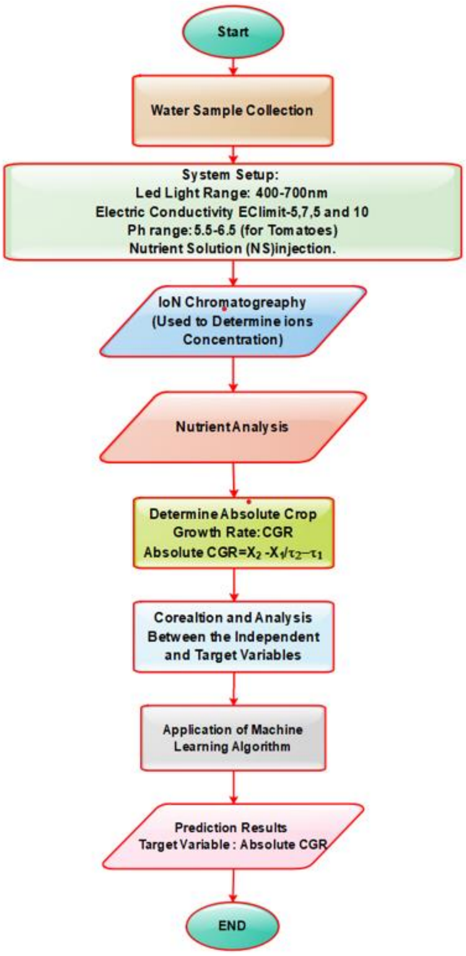

Figure 2. Proposed system of flowchart

4. DATA AND PREDICTION RATE ANALYSIS

4.1. Analysis of nutrients

A NI is considered as a liquid fertilizer resolution attuned in immovable arrangements so as to augment harvest development and defend it through nutrient shortages. The plant's requirement is satisfied over the nutrients ionic form provided over the water and added nutrient fertilizer. The interpretations were engaged over the duration of 140 days which is, 21 weeks around. The NI ingesting was mostly because of transpiration, since in a NFT scheme the vaporization is negligible, mentioned for a lone plant [20], [21].

4.2. Analysis of fruit

The disparaging samples (prior yield) of tomatos plant were engaged each in the weeks of around 2 to 3 till 55 days after transplantation (DAT) to define the ion acceptance examination of fruits magnesium (Mg), calcium (Ca), sodium (Na), potassium (K) and nitrogen (N) content. An obligatory draft oven was utilized to compute the dry matter weight and an equilibrium with 2 places of decimal was utilized, all observation standards are engaged in grams. The development factors comprised tomatos dry weight matter and plants absolute CYR [22]–[26].

5. RESULTS AND ANALYSIS

5.1. Complete development rate of the whole plant and stages of development of tomatos

The fruits were primarily seen on the plant through the early Phase I after 55 DAT, as depicted in Figure 3. The tomatos complete CYR remained 2.65 gms/day through this phase. Subsequently 76 days after NS explanation remained added numerous stints to the tomatos. In Phase II: (where in Fruit ripening happens) next 92 days an exponential development rate of the plant was seen having a maximum total CYR of x.28 grams per day. The NS novel plant was added many periods through such phase as well. In phase III (where in Fruit maturity and harvest happens), 117 DAT the fruits remained ripened and garnered, nevertheless a reduction in the complete CYR was seen at this phase having a worth of 2.8 grams per day.

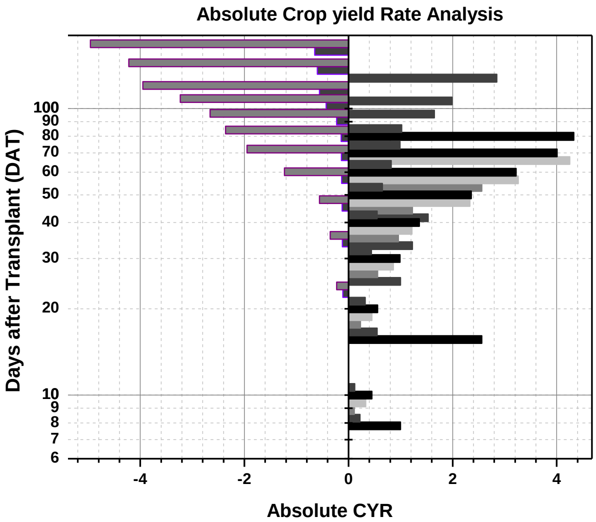

Figure 3. The proposed NFT-HNM analysis of absolute CYR for every tomatos plant over the period of 20 weeks (140 days)

5.2. The tomatos growth rate in different stages of nutrient ion (before and after harvesting) analysis and its impact on absolute CYR

The macro and micro-nutrient ion acceptances of the grape's berries throughout the whole development procedure of 140 days are shown in Tables 1 and 2. Grapes, like other plants, have specific macro and micronutrient requirements for healthy growth and development. Here are some key macro and micronutrients and their roles in grape cultivation.

Table 1. The tomatos crop yield rate (before harvesting)

	Ion-Concentration (Before Harvesting in gms)						
Crop yield Level	NA	Mg	Ca	N	K	DAT	Proposed CYR
Phase_1	1.01	1.08	0.82	0	22.199	57	2.6
Phase_2	0.86	1.06	0.79	1.74	24.87	71	1.33
	0.76	1.24	0.90	1.77	22.96	94	4.15
Phase_3	1.06	1.53	0.24	1.91	22.85	117	4.28
	1.33	1.56	1.002	1.78	25.66	129	-0.66
	1.66	1.75	1.009	1.80	24.54	142	-4.92
	1.43	1.19	0.82	1.97	31.55	158	0.02

Table 2. The tomatos crop yield rate (after harvesting)

	Ion-Concentration (After Harvesting in gms)						
Crop yield Level	NA	Mg	Ca	N	K	DAT	Dry Crop Weight
Phase_1	1.19	0.88	0.74	0	27.22	117	39.22
Phase_2	1.30	1.01	0.83	0	29.77	125	46.83
	1.35	1.02	0.97	0	30.65	131	35.12
Phase_3	1.53	1.18	0.79	0	32.48	140	27.45
	1.31	1.56	2.13	1.83	28.88	147	26.73
	1.35	1.03	0.95	1.49	30.11	159	37.99
	1.54	1.17	0.79	1.57	32.48	168	23.99

Figures 4 and 5 shows the crop weight analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. Figures 6 and 7 shows the sodium ion analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. The crop yield of tomatoes can vary depending on several factors, including cultivation practices, environmental conditions, tomato variety, and management techniques.

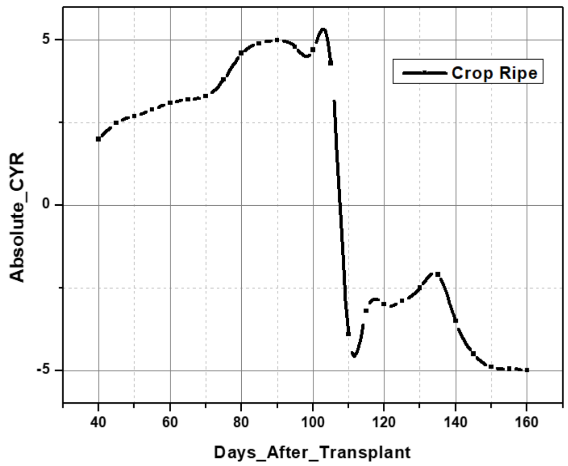

Figure 4. Crop weight analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

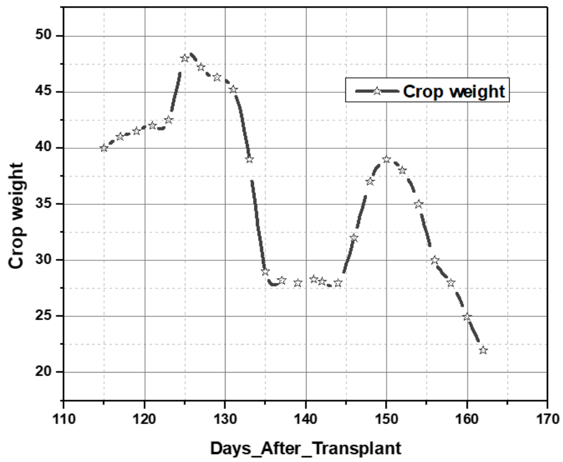

Figure 5. Crop weight analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

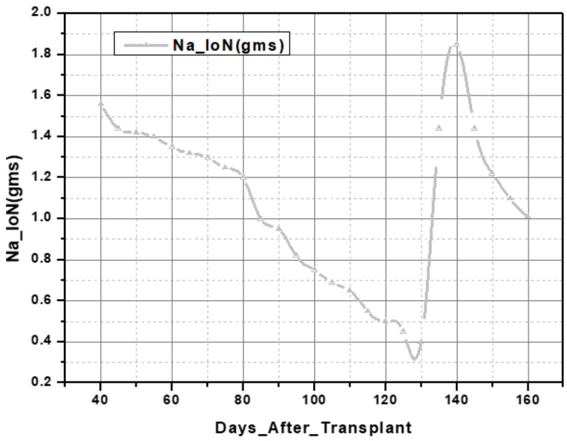

Figure 6. Sodium ion analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

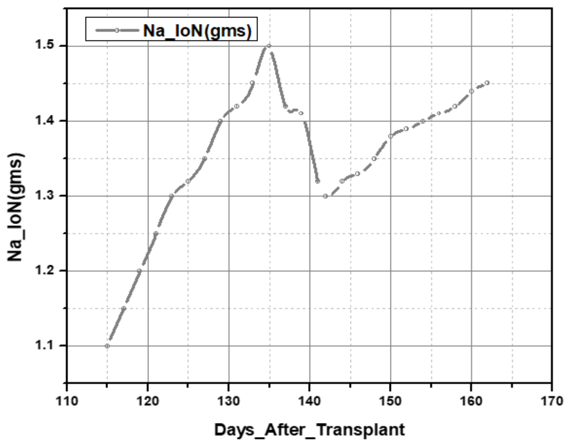

Figure 7. Sodium ion analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

Figures 8 and 9 shows the magnesium ion analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. Figures 10 and 11 shows the calcium ion analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. The crop yield of tomatoes can vary depending on several factors, including cultivation practices, environmental conditions, tomato variety, and management techniques.

Figures 12 and 13 shows the nitrogen analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. Figures 14 and 15 shows the potassium analysis of the tomatos before (I and phase II stages) and after harvest (phase III stages) respectively using proposed system. An incessant distribution of NS was preserved until 168 days through the phase 3, that showed an upsurge in the claim of ions by the plants, a minor upsurge of 0.099 in the CYR remained seen throughout the later phases of yield.

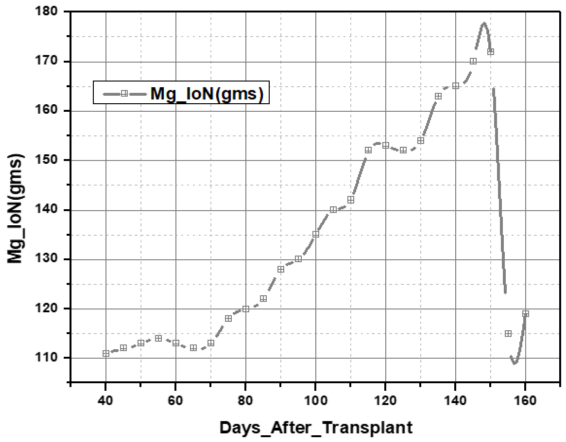

Figure 8. Magnesium ion analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

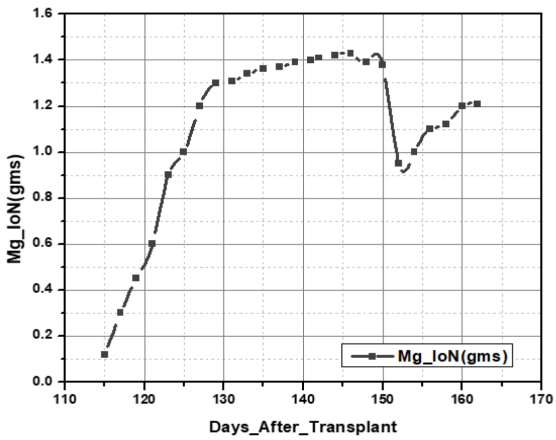

Figure 9. Magnesium ion analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

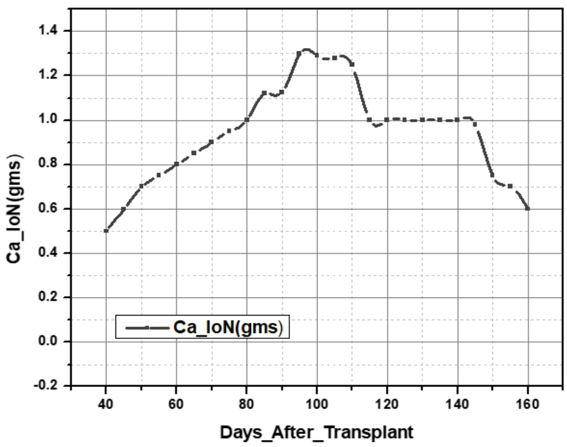

Figure 10. Calcium ion analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

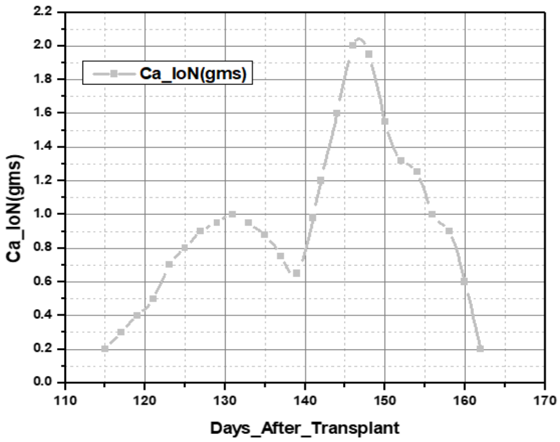

Figure 11. Calcium ion analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

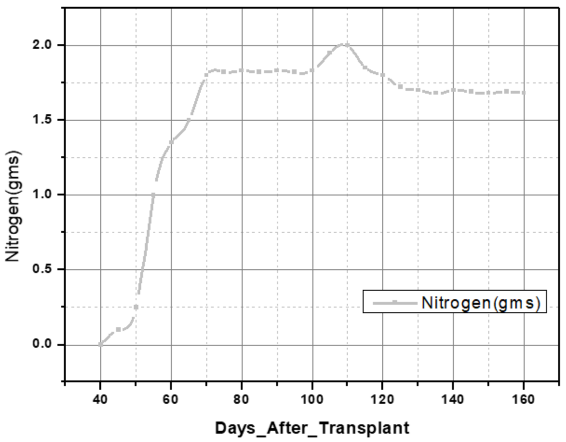

Figure 12. Nitrogen analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

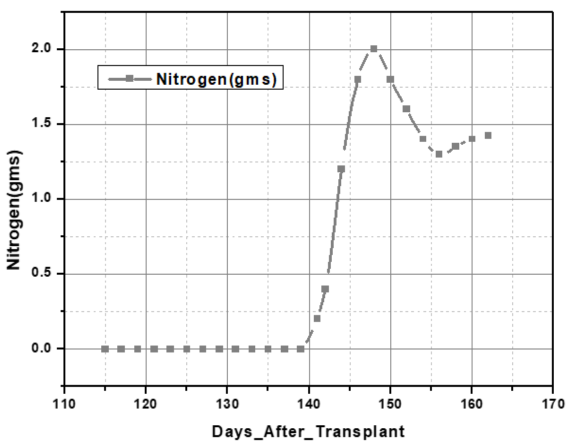

Figure 13. Nitrogen analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

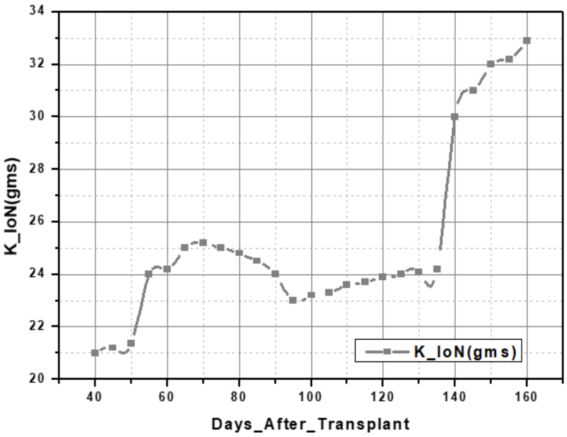

Figure 14. Potassium analysis of the tomatos (before harvest) in phase I and phase II stages and its analysis using proposed system

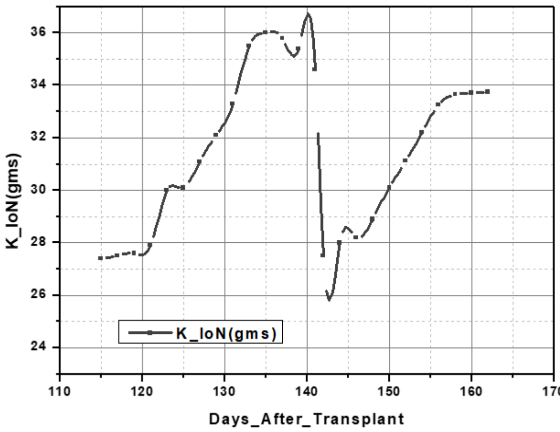

Figure 15. Potassium analysis of the tomatos (after harvest) in phase III stages and its analysis using proposed system

The ion upsurge rates remained in the directive K>N>Na>Mg>Ca throughout the phases (earlier and later yield). In the preliminary time of Phase I and Phase II (where in Fruit set and Fruit ripening happens) the absorption of the ion upsurge was seen in the range (0 to 1.79) gm $L^{-1}d^{-1}$, nevertheless the K ion depicted an important variant in the uptake with peak values of uptake in range (22 to 34) gm L^{-1} d^{-1} The acceptance rates of the nutrients augmented expressively when the fruits matured and remained ready to yield till day 143. The difference tendencies in ion absorption represent a growing tendency for all the ions after 94 and uppermost absolute CYR (4.28 gm d^{-1}) was seen parallelly. In the future time a declining tendency was seen for the CYR and captivation stages of all the ions excluding K ions correspondingly. The extreme uptake rates of K, N, Na, Mg and Ca was 32.48, 1.91, 1.68, 1.75 and 1.25 gm $L^{-1}d^{-1}$ correspondingly. Figure 15 depicts the nutrient acceptances dynamics since day 117, the yield phases and its influence over the dry weight matter of the fruits. The absorption of nitrogen remained seen to be too low and that is why it was not seen till day 138. Dry weight substances of the fruits recorded an upsurge till 125. A quick reduction in weights was seen until day 147. The tendencies in dissimilarity for Mg, N, Na, Ca and K ions did not track the tendencies in disparity of the dry weight matter. Extreme concentrations standards seen were 1.68, 1.009, 1.75, 1.91,31.48 respectively.

We projected and premeditated a bendable structure for HNM which could be castoff in the forecast of the complete CYR. The three phases in the scheme are dependent through each other and target to forecast the CYR in a relaxed way using input parameters significant through the development procedure. The ecological situations fixed in the NFT closed hydroponic scheme remained decent to assist the ideal farming of the tomatos. A thorough investigation depicts the nutrient concentrations and undercurrents of ions uptakes of Na Ca, N, Mg, K at diverse phases of tomatos development. The absolute CYR of the plant was computed and perceived for every dissimilar phase of the. Any important variations were not seen amid the absolute CYR and the dissimilar phases of fruit development. The association investigation later recommended the input parameters that had a robust influence on the development factors similar to dry weight of the complete fruits. It stood like nutrient ion Na required the uppermost association, such ions improve the progress and expansion of the tomatos and likewise donate in refining the flavors of the eatable parts. Ca had a bottommost rate of acceptance and the feeblest association in the dry weight matter of fruits, showing the quantity in the nutrient elucidation seen was not ideal for development of tomatos. The K and Mg ions had optimistic relationships and dissimilarity trends through the development procedure. Raised stages of K ions can progress the fruits. Sophisticated EC values show additional ions in the result. The EC boundary persisted perpetual (5, 7.5, 10) through the development of tomatos showing that a comparable quantity of ions was seen at this intermission. Such results show that precise ion monitoring and adjustments are for healthier uptakes that can outcome in respectable development and growth of the plants in HNM.

6. CONCLUSION

The proposed hydro-crop growth prediction system (HCGPS) is used to predict crop yield rate using machine learning by adopting HNM method. The proposed system's process is reconfigured to reduce the complexity to achieve the better-quality crop growth and yield rate. The proposed HNM is used to analyze Effects of straw return with N fertilizer reduction on crop yield, plant diseases and pests and potential heavy metal risk in a Chinese rice paddy: A field study of 2 consecutive wheat-rice cycles the water nutrients and its concentration to get better crop growth and yield rate. The proposed method improves the Na and K ion uptake 0.98% and 1.025% respectively as compared to conventional methods. According to the analysis, the Ca ion utilization is very low (0.78%) during entire crop growth process. this indicates better adjustment of NI. The proposed HCGPS regularly monitors the various ions instead of ECL based control. due to this, it prevents the nutrient deficiencies during absorption process to get better yield of tomatos. The machine learning based HCGPS provides the information and prediction rate of water nutrients index and reduces the complexity during the process to get better crop yield prediction rate.

7. FUTURE SCOPE

The proposed system can predict the crop yield rate using machine learning algorithm. But when prediction analysis will be done on huge varieties of crops and climate changes, the system has to be developed using random forest and deep neural network.

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