Inoculation of maize with 1-Aminocyclopropane-1-carboxylic acid containing *Pseudomonas fluorescens* for enhanced available nutrients in soils of Maize (*Zea mays* L.)

ABSTRACT

A field experiment entitled "Inoculation of maize with 1-Aminocyclopropane-1-carboxylic acid containing *Pseudomonas (P)fluorescens* for enhanced available nutrients in soils of Maize (*Zea mays* L.)" was conducted at Research Farm, Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during 2018-19. The results revealed that the available nitrogen (N) content in soil at knee height, tasseling and silking stage, the treatment combination Temperature 28^{o}C and pH 7.2 (T_{28}+pH 7.2) isolates significantly increase the N content in soil with response of 21.5,17.3 and 14.4% over FUI (209, 196 and 166 kg N ha^{-1}), respectively. Similarly, the isolates of T_{28}+pH 7.2 significantly increase the available phosphorus (P) content at knee height, tasseling and silking stage in soil with response of 31.7, 23.2 and 26.4% over FUI (18.0,16.4 and 14.4 kg P ha^{-1}). The isolates of T_{28}+pH 7.2 significantly increase the available potassium (K) content in soil at knee height, tasseling and silking stage with response of 14.4, 10.1 and 10.4% over FUI (298, 278 and 264 kg K ha^{-1}).

Keyword: ACC-deaminase; maize, inoculation, plant growth promoting rhizobacteria, yield.

1. Introduction

Maize (Zea mays L.) is an important crop in temperate and semi-arid regions and one of the three major food staple crops for the world's population. India occupies fifth place in acreage and ranks 10th in production. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. The average productivity in India is 1959 kg ha^{-1} grown in 7.18 million hectares area contributing 14.1 MT of production, and the crop is the third most important food crops after rice and wheat (Agriculture Statistics at a glance, 2016). The state of Madhya Pradesh occupies 13% of the total maize area and contributing equally to the total maize production in the country. Nutritionally, maize contains 60 to 68% starch, 1.2 to 5.7% edible oil and 7 to 15% protein (Singh *et al.*, 2003).

Numerous agricultural soils worldwide are deficient in plant nutrients. Hence, significant fertilizer requirement is a major challenge for sustainable food production. Previously, these plant nutrients were provided solely in the form of synthetic chemical fertilizers. Such chemical fertilizers are quite expensive and increase crop production cost. In addition, chemical fertilizers lead to soil degradation and pose health hazard to both human and farm animals (Alori and Babalola 2018). It is therefore imperative to improve soil fertility, while at the same time preventing associated negative environmental effects of chemical fertilizers. Microbial inoculants are of growing interest for their potential role in improving soil fertility and enhancing an increase in crop yields and their nutrient contents. Microbial inoculants are the formulations composed of beneficial microorganisms that play important role in every ecosystem. When applied to seeds, soil or seedlings, microbial inoculants improve directly or indirectly the nutrient availability to the host plant and promote plant growth (Babalola et al 2007; Rokhzadi et al 2008). In the present agricultural practices, there is a number of beneficiary soil microorganisms used as inoculants. They include *Pseudomonas*sp, *Azospirillum*, *Azotobacter* and *Phosphobacterium* among others (Babalola and Akindolire 2011; Alori et al 2017). Microbial inoculants improve plant growth through a number of mechanisms which include the production of plant hormones, the supply of nutrients and the suppression of various crop pests (Toota and Watanable 2013).

2. MATERIALS AND METHODS

The present field investigation was carried out in 2 phases as Component- I (during rainy season of 2018): Kinetics of population growth of *P. fluorescens* and 1-Aminocyclopropane-1-carboxylic acid deaminease (ACCD) activity of the bacteria under different conditions of fermentation; and Component- II (during winter season of 2019): performance of selected isolates of *P. fluorescens* on maize. Studies of component- I and II were performed at the Laboratory of Microbes Research & Production Centre and the Research Farm, Department of Soil Science & Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur India, (latitude of 23° 13 ' N and longitude of 79° 57' E with an altitude of 393 m above mean sea levels) in the period of Feb-June, 2019. The field soil was deep black soil in texture, having pH, 7.48; organic carbon; 0.53%, available N, 233 kg ha-1 and 14.9 kg ha-1 of available P and 209 kg ha^{-1} of available K, respectively and *P. fluorescens* population (1.35×104 cfu g-1 soil) was recorded) respectively. Under fermentation experiment a local but effective strain of *P.*

fluorescens was batch cultured for 13 intervals of time (at 0, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132 and 144 hr) with 16 treatments including four temperature regimes (i.e., 25, 28, 31, 34°C), four pH (i.e., 6.7, 7.2, 7.7, 8.2) and their interaction under Randomized block designs (RBD) factorial design. Broth samples were drained out from the fermentator at the scheduled intervals for study on the bacterial population growth and enzyme ACCD activity. Under field study, the 16 isolates derived from the treatments of different temperature and pH with additional 2 controls [Total treatments = 18 (16 isolates + 1 FUI + 1 UFUI)] were tried on maize following RBD design with 3 replications. Data were statistically treated by ANOVA, RBD to test the statistical significance of variance among different treatment means as influenced with the application of the treatments on various attributes of maize.

2.1. Climate

The tropic of cancer passes through the middle of the district. It has sub-tropical climate characterized by hot dry summers and cool dry winter. Jabalpur lies in the "Kymore Plateau and Satpura hills" agro- climatic zone of Madhya Pradesh. Seasonal variations prevailing during the growing period plays an important role in the developmental process, which may have great influence on the final yield of the crop. The weekly meteorological data were recorded during crop season of Meteorological Observatory College of Agricultural Engineering, JNKVV, Jabalpur and are depicted through Figure 1. It is obvious from the meteorological data that the weather conditions which prevailed during the crop season were favorable for the growth and development of maize. The mean weekly maximum temperature ranges from (26.2 to 44.4°C) whereas; mean weekly minimum temperature ranged between 3.1 to 27.3°C. Whereas, relative humidity varied from 49.0 to 85.0 % in morning and 17.0 to 47.0% in evening. The mean sunshine hours varied between 7.3 to 10.3 hours per day. Total rainfall of 77.3 mm was received.

2.2. Seed inoculation, treatment and sowing

The isolates of *P. fluorescens* obtained from the laboratory experiment (Component I) performing best for population growth and ACCD enzyme activity were earmarked and specially selected for the field trial on maize to observe sustainability of the attributes. However, remaining other isolates along with the selected isolates was also included in the field trial. The isolates in broth were used for seed treatment and foliar spray on maize at three growth stages (at knee stage, tasselling and silking stage) to ascertain the population growth attributes and ACCD activity in rhizosphere and the plant growth and yield at maturity. Maize seeds in polythene bags were slightly moistened and then treated with carbendazim fungicide 2 g kg^{-1} seed and air dried under shade. Then the seeds were inoculated individually with the isolated of *P. fluorescens* the recommended dose 10 ml kg^{-1} of seed and using sterilized gum acacia (2%) as adhesive. The field experiment was carried out at research farm JNKVV Jabalpur during winter season of 2019. The seeds of maize (JM-216) were sown in the respective plot. Recommended package of practices (Depth of Sowing: 4-6 cm, where maize is generally sown on flat beds. Spacing: 70cm x 25cm for row to row and plant to plant. Plant density of 66,666/ha and intercultural operation) was followed to maintain plant population, protection and growth.

2.3 Analysis of soil samples

The surface (0-15 cm) soil samples were collected from the experimental site at knee height, tasseling stage and silking stage of maize crop. The soil samples were air dried and crushed with wooden pestle and mortar and sieved through 2 mm sieve. The material passed through the sieve was used for determination of various characters. Available nitrogen in soil sample was determined by using alkaline permanganate method (Subbiah and Asija, 1956). A known weight of soil is mixed with excess of alkaline permanganate and distilled. Organic matter present in soils is oxidized by the nascent oxygen liberated by $KMnO_4$ in the presence of NaOH and thus ammonia is released. This released ammonia was absorbed in the boric acid (2%) solution containing mixed indicator and converted to ammonium borate. This ammonium borate was titrated with standard sulphuric acid. The available phosphorus content in soil was estimated by extraction procedure as described by Olsen et al. (1954). Soil available phosphorus was extracted using 0.5 M $NaHCO_3$ (pH 8.5) and determination was done by ascorbic acid method as described by Miller and Keeney (1982). The available potassium was extracted with neutral 1 N ammonium acetate as described by (Jackson, 1973) and determined by Flame photometer.

3. RESULTS AND DISCUSSION

Results of field experiments revealed that inoculation with selected *P. fluorescens* isolates, containing ACCD activity, under field conditions significantly promoted the available nutrients in soil. However, the rate of enhancement varied with isolates obtained from component (I). Inoculation of rhizobacterial isolates in the presence of chemical fertilizer significantly increased available nutrients in soil of maize.

Available nitrogen in soil

The data regarding available nitrogen contents in surface soil (up to 0-15 cm depth) at knee height, tasseling and silking stage of the crop are presented in Table 1.

At knee height stage

The available N content in soil at knee height stage varied from 194 to 254 kg N ha^{-1} with the mean value of 237 kg N ha^{-1}. The isolates of T_{28}+pH 7.2 significantly increase the N content 254 kg N ha^{-1} in soil with response of 21.5% over FUI (209 kg N ha^{-1}) followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7, T_{28}+pH 6.7, T_{31}+pH 6.7, T_{34}+pH 6.7 and T_{25}+pH 6.7 with N content in soil of 252, 250, 249, 246, 246, 245, 241, 240, 238 and 237 kg N ha^{-1} by 20.6, 19.6, 19.1, 17.7, 17.7, 17.2, 15.3, 14.8, 13.9 and 13.4% response, respectively over the FUI.

At tasseling stage

The available N content in soil at tasseling stage increased from 179 to 230 kg N $ha^{-1}$with mean value of 214 kg N ha^{-1}. On comparing all the treatments, the available N content of 230 kg N ha^{-1} was found significantly superior by the application of T_{28}+pH 7.2 as compared to control FUI (196 kg N ha^{-1}) and it was responded by 17.3%, followed by the treatment combination T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7, T_{28}+pH 6.7, T_{31}+pH 6.7 and T_{34}+pH 6.7 with N content in soil 229, 227, 225, 223, 221, 220, 218, 217 and 213 kg N ha^{-1} along with 16.8, 15.8, 14.8, 13.8, 12.8, 12.2, 11.2, 9.7 and 8.7% response, over FUI.

At silking stage

The N content in soil at silking stage varied from166 to 206 kg N ha^{-1} with average value of 191 kg N ha^{-1}. Among the treatments, the available N content of 206 kg N ha^{-1} in soil at surface layer was found statistically superior by the use of T_{28}+pH 7.2 as compared to FUI (166N kg ha^{-1}) and it was responded about 14.4% followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7, T_{28}+pH 6.7 and T_{31}+pH 6.7 with 205, 204, 203, 200, 198, 197 and 193 kg N ha^{-1} in soil at surface layer along with 13.9, 13.3, 12.8, 11.1, 10.0, 9.4 and 7.2% response, over FUI.

Rhizobial strains that express ACC deaminase are up to 40% more efficient at forming nitrogen-fixing than strains that lack this activity. The slight buildup of the soil available N could be attributed to increased activity of nitrogen fixing and phosphate solubilizing rhizobacteria thereby resulting in higher accumulation of N in the soil (Kumar and Singh, 2010). Levels of these were increased over a period of time due to their residual or cumulative effect through addition of these nutrients. Patidar and Mali (2004); Chand (2007) and Dadhich *et al*., (2011) also observed increased available N content in soil after the harvest of the crop due application of microbial inoculants as compared to no inoculation.

Available phosphorus in soil

The data regarding available P contents in surface soil (up to 0-15 cm depth) at knee height, tasseling and silking stage of the crop are presented in Table 2.

At knee height stage

The available P content in soil at knee height stage varied from 16.8 to 23.7 kg P ha^{-1} with the mean value of 21.7 kg P ha^{-1}. The isolates of T_{28}+pH 7.2 significantly increase the P content (23.7 kg P ha^{-1}) in soil with response of 31.7% over FUI (18.0 kg P ha^{-1}) followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7 and T_{31}+pH 7.7 with P content in soil of 23.0, 22.8, 22.6, 22.5 and kg P ha^{-1} by 27.8, 26.7, 25.6, 25.0 and 24.4% response, respectively over the FUI.

At tasseling stage

The available P content in soil at tasseling stage increased from 15.5 to 20.2 kg P ha^{-1} with mean value of 18.0 kg P ha^{-1}. On comparing all the treatments, the available phosphorous content of 20.2 kg P ha^{-1} was found significantly superior by the application of T_{25}+pH 7.2 as compared to control FUI (16.4 kg P ha^{-1}) and it was responded by 23.2%, followed by the treatment combination T_{31}+pH 7.2, , T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7 and T_{31}+pH 7.7 with P content in soil 19.7, 19.5, 19.2, 19.0 and 19.0 kg P ha^{-1} along with 20.1, 18.9, 17.1, 15.9 and 15.9% response, over FUI.

At silking stage

The available P content at silking stage varied from 13.8 to18.2 kg P ha^{-1} with average value of 16.1 kg P ha^{-1}. Among the treatments, the available P content of 18.2 kg P ha^{-1} in soil at surface layer was found statistically superior by the use of T_{28}+pH 7.2 as compared to FUI (14.4 kg P ha^{-1}) and it was responded about 26.4%, followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7 and T_{31}+pH 7.7 with 17.7, 17.5, 17.2, 17.0 and 17.0 kg P ha^{-1} in soil at surface layer along with 22.9, 21.5, 19.4, 18.1 and 18.1% response, over FUI.

The availability of P status of soil improved due to PGPR may be ascribed to increased solubility of unavailable native soil phosphate with exotic strains of PSB besides extraction of P from deeper layers by VAM hyphae (Dadhich *et al*., 2011). Results were also in accordance with the findings of Chand (2007) and Singh *et al*., (2013); Namdeo *et al*., (2017); Chalie-u and Jakhar, (2018); Yaduwanshi *et al*. 2019); Parewa *et al*., (2014) that the result revealed that application of fertilizer levels, FYM and bioinoculants on soil properties in inceptisol of varanasi, uttar pradesh, india. The available N, P and K and microbial population of soil after the harvest of wheat were improved significantly due to the integration of inorganic fertilizers with FYM and bioinoculants. Positive impact of biological and organic manure application have been recorded with an additional advantage of reduction of chemical fertilizer use.

Available potassium in soil

The data regarding available potassium contents in surface soil (up to 0-15 cm depth) at knee height, tasseling and silking stage of the crop are presented in Table 3.

At knee height stage

The available K content in soil at knee height stage varied from 273 to 341 kg K ha^{-1} with the mean value of 326 kg K ha^{-1}. The isolates of T_{28}+pH 7.2 significantly increase the K content 341 kg K ha^{-1} in soil with response 14.4% over FUI (298 kg K ha^{-1}), followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7 and T_{28}+pH 6.7 with K content in soil of 338, 337, 336, 335, 334, 332, 332 and 330 kg K ha^{-1} by 13.4, 13.1, 12.8, 12.1, 11.4, 11.4 and 10.7% response, respectively over the FUI.

At tasseling stage

The available K content in soil at tasseling stage increased from 267 to 306 kg K ha^{-1}with mean value of 295 kg K ha^{-1}. On comparing all the treatments, the available K content of 306 kg K ha^{-1} was found significantly superior by the application of T_{28}+pH 7.2 as compared to control FUI (278 kg K ha^{-1}) and it was responded by 10.1%, followed by the treatment combination T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7 and T_{28}+pH 6.7 with K content in soil 305, 303, 302, 301, 299, 299 and 298 kg K ha^{-1} along with 9.7, 9.0, 8.6, 8.3, 7.6, 7.6 and 7.2% response, over FUI.

At silking stage

The K in soil at silking stage varied from 255 to 291 kg K ha^{-1} with average value of 279 kg ha^{-1}. Among the treatments, the available K content of 291 kg K ha^{-1} in soil at surface layer was found statistically superior by the use of T_{28}+pH 7.2 as compared to FUI (264 kg K ha^{-1}) and it was responded about 10.4% followed by T_{31}+pH 7.2, T_{25}+pH 7.2, T_{34}+pH 7.2, T_{28}+pH 7.7, T_{31}+pH 7.7, T_{25}+pH 7.7, T_{28}+pH 6.7 and T_{31}+pH 6.7 with 289, 288, 282, 287, 285, 283, 283 and 281 kg K ha^{-1} in soil at surface layer along with 9.6, 9.2, 7.0, 8.8, 8.1, 7.3, 7.3 and 6.6% response, over FUI.

The beneficial effect of PGPR on K availability includes minimizing the losses due to fixation as well as release of K through the action of organic acids librated during decomposition. The results were in accordance with the findings of Dadhich *et al*., (2011) and Singh *et al*., (2012). Jakhar *et al*., (2018a). Pandey *et al.*,(2015) also reported that combined inoculation of Rhizobium, PSB and PGRR improved the nutrient status of soil through their synergistic effect on nitrogen fixation and solubilisation of native soil phosphorus which increased availability these nutrients by the crop plant (Urd bean) resulted in enhanced yield indices. Jakhar *et al*. (2017); Prasad *et al*., (2001) Seed inoculation with biofertilizers enhanced available N, P, K contents of the soil.

5. REFERENCES

Alori ET, Babalola OO. 2018. Microbial inoculant for improving crop quality and human health. Front Microbiol; 9: 2213.

Alori ET, Dare MO, Babalola OO. 2017. Microbial inoculants for soil quality and plant health; 281-308.

Anomyous. 2016. Agricultural statistics Division Directorate of Economics & Statistics Department of Agriculture & Cooperation, Govt of India.

Babalola OO, Akindolire AM. 2011. Identification of native rhizobacteria peculiar to selected food crops in Mmabatho municipality of South Africa. Bio Agric Hort. An Int J Sustain Prod Sys; 27(3-4): 294-309.

Babalola OO, Sanni AI, Odhiambo GD, Torto B. 2007. Plant growth-promoting rhizobacteria do not pose any deleterious effect on cowpea and detectable amounts of ethylene are produced. World J Microbiol Biotechnol; 23: 747-52.

Chalie-u, R. and Jakhar, SR. 2018. Prospects of *Trichoderma* in Agriculture-Fundamentals and Applications International Journal of Current Microbiology and Applied Sciences, 7(6): 3519-3527.

Chand S. 2007. Effect of integrated nutrient management on yield and nutrient use efficiency in mustard (*Brassica juncea* L.). SAARC Journal of Agriculture 5(2): 93-100.

Dadhich SK, Somani LL and Shilpkar D. 2011. Effect of integrated use of fertilizer P, FYM and biofertilizers on soil properties and productivity of soybean-wheat crop sequence. Journal of Advances in Developmental Research 2(1): 42-46.

Jackson ML. 1973. Soil chemical Analysis. Prentice Hall of Englewood cliffs, New Jersey, USA.

Jakhar SR, Kumar S, Jangir CK and Meen RS. 2017. The role of mycorrhizal relationship in sustainable manner towards plant growth and soil fertility. Indian Journal of Agriculture and Allied Sciences 3(4): 19-24.

Jakhar SR, Tiwari R, Chaudhary BK and Kumhar BL. 2018a. PGPR: Heart of soil and their role in sustainable agriculture. Rashtriya krishi 13(1): 150-107.

Kumar V and Singh AP. 2010. Long-term effect of green manuring and farmyard manure on yield and soil fertility status in rice-wheat cropping system. Journal of the Indian Society of Soil Science 58(4): 409-412.

Miller RH, and Keeney DR. 1982. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Circular* United States *Department of Agriculture* 939:1-20.

Namdeo V, Mitra NG, Jakhar SR and Prahlad. 2017. To assess the effect of different levels of nitrogen and inoculation of *Azospirillum* on crop growth and yield of paddy. I*nternational Journal of Chemical Studies*, 5(4): 821-826.

Olsen SR, Cole CV, Vatanabe FS and Dean LA. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Circular United States Department of Agriculture 939:1-19*.

Pandey IB, Pandey RK and Kumar R. 2015. Integrated nutrient management for enhancing productivity and profitability of long duration pigeon-pea (Cajanus cajan) under rainfed condition. Indian Journal of Agronomy 60(3): 436-442.

Parewa HP, Yadav J and Rakshit A. 2014. Effect of Fertilizer Levels, FYM and Bioinoculants on Soil Properties in Inceptisol of Varanasi, Uttar Pradesh, India. International Journal of Agriculture, Environment & Biotechnology 7(3): 517-525.

Patidar M and Mali A. 2004. Effect of farmyard manure, fertility levels and bio-fertilizers on growth, yield and quality of sorghum (*Sorghum bicolor*). Indian Journal of Agronomy 49(2): 117-120.

Prasad R and Mishra BN. 2001. Effect of addition of organic residue, farmyard manure and fertilizer nitrogen on soil fertility in rice-wheat cropping system. Archives of Agronomy and Soil Science 46:455-463.

Rokhzadi A, Asgharzadeh A, Darvish F, Nourmohammadi G, Majidi E. Influence of plant growth-promoting rhizobacteria on dry matter accumulation and yield of chickpea (*Cicer arietinum* L.) under field condition. Amer.-. Euro J Agric Environ Sci 2008; 3(2): 253-7.

Singh R. 2012. Need to optimize resources use efficiency for sustainable agriculture. Journal of Indian Society of Soil Science 60:100-108.

Singh NK, Chaudhary FK and Patel DB. 2013. Effectiveness of *Azotobacter* bio-inoculant for wheat grown under dryland condition. Journal of Environmental Biology 34:927-932.

Singh RP, Kumar R and Singh NP. 2003. Transformation of the Indian maize economy - Different perspectives. In maize production in india-golden grain in transition TB-ICN 4:1-28.

Subbiah BV and Asija EC. 1956. A rapid procedure for estimation of available nitrogen in soil. Current Sciences 25:259-260.

Toyota K, Watanabe T. 2013. Recent trends in microbial inoculants in agriculture. Microbes Environ; 28(4): 403-4.

Yaduwanshi B, Sahu RK, Mitra, NG, Amule, FC and Jakhar, SR. 2019. Effect of microbial consortia on growth, nodulation, yield and nutrient uptake of soybean in vertisol of central india. International Journal of Current Microbiology and Applied Sciences, 8(9): 2649-2659.

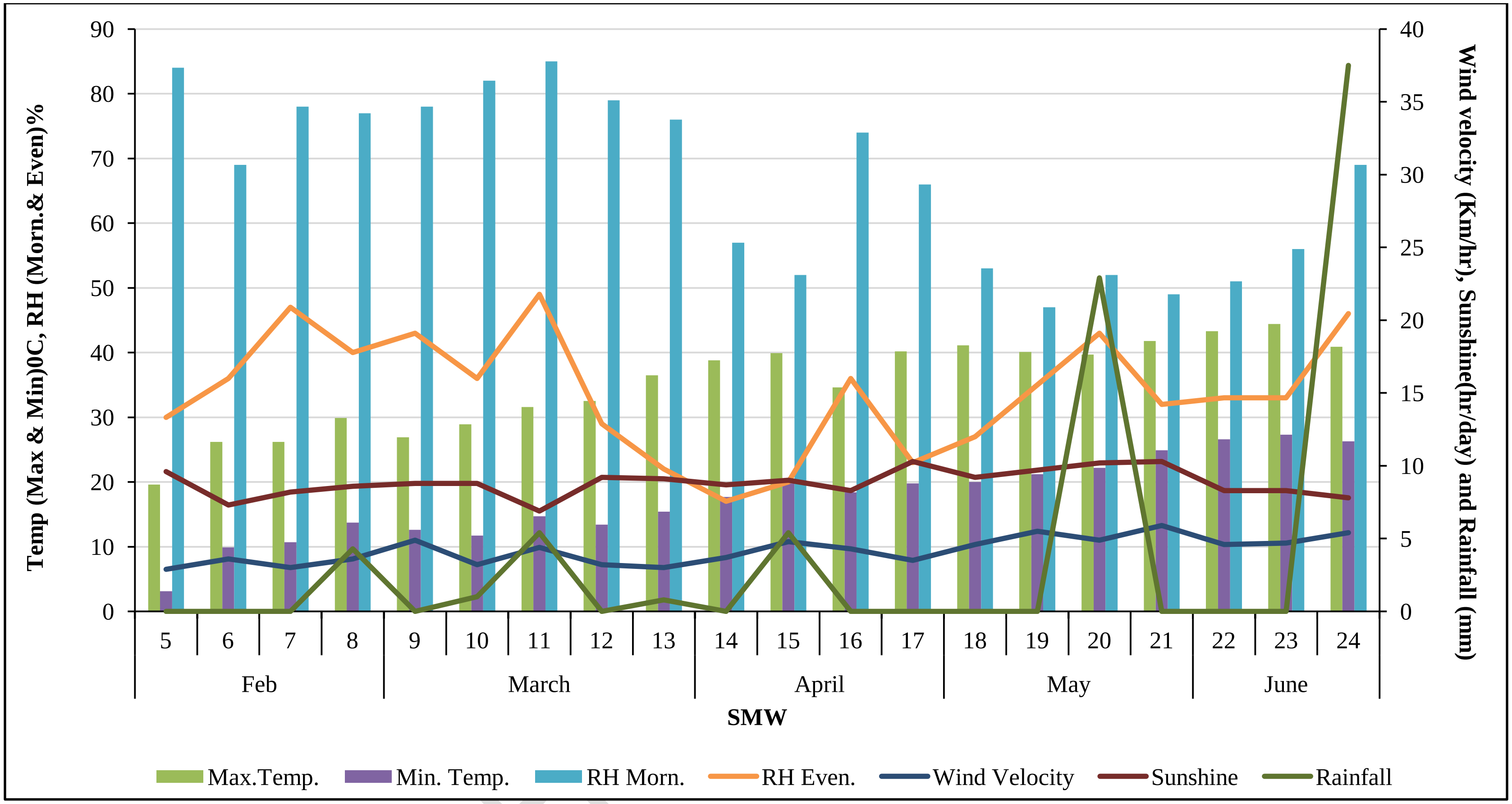

Fig. 1: Weekly meteorological data during Feb - Jun, 2018-19

Table 1. Effect of selected isolates of *P. fluorescens* on available nitrogen in soil of maize at different growth stages

Treatment combination	Available N (kg ha^{-1})		
	knee height	Tasseling stage	Silking stage
T_{25}+pH 6.7	237	212	189
T_{25}+pH 7.2	250	227	204
T_{25}+pH 7.7	245	220	197
T_{25}+pH 8.2	233	208	185
T_{28}+pH 6.7	241	218	193
T_{28}+pH 7.2	254	230	206
T_{28}+pH 7.7	246	223	200
T_{28}+pH 8.2	235	210	187
T_{31}+pH 6.7	240	215	192
T_{31}+pH 7.2	252	229	205
T_{31}+pH 7.7	246	221	198
T_{31}+pH 8.2	235	210	187
T_{34}+pH 6.7	238	213	190
T_{34}+pH 7.2	249	225	203
T_{34}+pH 7.7	230	205	182
T_{34}+pH 8.2	229	204	181
FUI	209	196	180
UFUI	194	179	166
Mean	237	214	191
SE_m±	9.2	5.6	4.2
$CD_{5\%}$	27.0	16.4	12.5

Table 2. Effect of selected isolates of *P. fluorescens* on available phosphrous in soil of maize at different growth stages

Treatment combination	Available P (kg ha^{-1})		
	knee height	Tasseling stage	Silking stage
T_{25}+pH 6.7	20.5	17.7	15.7
T_{25}+pH 7.2	22.8	19.5	17.5
T_{25}+pH 7.7	21.6	18.7	16.7
T_{25}+pH 8.2	19.2	17.2	15.2
T_{28}+pH 6.7	21.3	18.4	16.4
T_{28}+pH 7.2	23.7	20.2	18.2
T_{28}+pH 7.7	22.5	19.0	17.0
T_{28}+pH 8.2	19.9	17.5	15.5
T_{31}+pH 6.7	21.1	17.8	15.8
T_{31}+pH 7.2	23.0	19.7	17.7
T_{31}+pH 7.7	22.4	19.0	17.0
T_{31}+pH 8.2	19.6	17.2	15.2
T_{34}+pH 6.7	20.8	18.0	16.0
T_{34}+pH 7.2	22.6	19.2	17.2
T_{34}+pH 7.7	18.9	16.9	14.9
T_{34}+pH 8.2	18.5	16.7	14.7
FUI	18.0	16.4	14.4
UFUI	16.8	15.5	13.8
Mean	20.7	18.0	16.1
$SE_m\pm$	1.3	0.8	0.8
$CD_{5\%}$	3.8	2.3	2.5

Table 3. Effect of selected isolates of *P. fluorescens* on available phosphrous in soil of maize at different growth stages

Treatment combination	Available K (kg ha^{-1})		
	knee height	Tasseling stage	Silking stage
T_{25}+pH 6.7	327	295	279
T_{25}+pH 7.2	337	303	288
T_{25}+pH 7.7	332	299	283
T_{25}+pH 8.2	323	293	276
T_{28}+pH 6.7	332	298	283
T_{28}+pH 7.2	341	306	291
T_{28}+pH 7.7	335	301	287

T_{28}+pH 8.2	326	295	278
T_{31}+pH 6.7	330	297	281
T_{31}+pH 7.2	338	305	289
T_{31}+pH 7.7	334	299	285
T_{31}+pH 8.2	325	294	277
T_{34}+pH 6.7	328	296	280
T_{34}+pH 7.2	336	302	282
T_{34}+pH 7.7	322	292	276
T_{34}+pH 8.2	322	291	275
FUI	298	278	264
UFUI	273	267	255
Mean	326	295	279
SE_m±	10.3	6.6	5.6
$CD_{5\%}$	30.2	19.4	16.5