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SCHEDULING OF IRRIGATION AND NITROGEN FERTILIZER APPLICATION FOR GROWING CABBAGE ON RAISED-BEDS

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ABSTRACT

Proper scheduling of irrigation and fertilizer is necessary for better crop production and soil health under the climatic condition of a particular region. We conducted a field experiment to develop proper schedule of irrigation and urea fertilizer applications for cabbage under field condition during 2017. Following four irrigation and urea fertilizer scheduling treatments with three repeats were tested in the study: T1: 5 days, T2: 15 days, T3: 25 days and T4: (15 days no fertilizer). The results showed that the soil density (ρ_d) EC (dS m^{-1}), SAR, ESP and Cl^- increased, whereas the soil porosity (η), void ratio (e) and pH decreased significantly with the frequent irrigation and fertilizer scheduling. The macro-nutrients in the soil i.e. nitrogen, phosphorous and potash increased under all treatments, except without fertilization. The nitrogen, phosphorous and potash contents of the soil were found maximum at 25 days irrigation and urea fertilization scheduling compared to 5, 15 and control. The yield of cabbage increased from 6-51% and water productivity increased from 15-55% with 25 days irrigation and urea fertilization scheduling compared to 5, 15 and content. The irrigation and urea fertilizer may be applied to cabbage crop with the schedule of 25 days.

Keywords: fertilizer, irrigation, scheduling, water productivity, yield

INTRODUCTION

The freshwater resources of Pakistan are continuously depleting due to the increasing demand of the rapidly growing population, industrialization, urbanization and other national users (Qureshi *et al*., 2011). During the last 10 years, the availability of surface water at the canal heads has decreased from 127.5 BCM to 116 BCM (GoP, 2014). By the year 2025, the shortfall of water requirements will be 32%, which will result in a food shortage of 70 million tons (Qureshi, 2011). Thus, it is a great challenge for the agricultural sector to produce more food for ever increasing population of the country without imperiling the resources (Kumari *et al*., 2014). In Pakistan, the farmers apply irrigation without considering the water requirement of crops, leading to application efficiency between 40 to 50% (Ishfaq, 2002). Moreover, the soil environmental problems are substantial due to the excessive fertilization (Zhang *et al*., 2015; Rizwan *et al*., 2016; Xie *et al*., 2017) leads to increase nitrate content in the groundwater (Li *et al*., 2018). The yield and quality of vegetables are mainly affected by water and fertilizer (Schwarz *et al*., 2010). The crop growth and nutrient absorption can effectively be promoted with an effective irrigation and fertilizer scheduling. Many researchers have conducted experiments to assess the impact of different irrigation and fertilization intervals on the crop yield, yield traits and soil properties. Al- Solaimani *et al*. (2015) found that at 15 days interval of irrigation and nitrogenous fertilization the yield and yield parameters of canola increased significantly. Gerami *et al*. (2016) found highest oregano seeds oil content of 2.07 percent with 21 days irrigation interval. Matthew (2016) found highest pepper yield and agronomical variables while applying irrigation along with the moringa leaf extract as a fertilizer after 14 days interval. Yargholi and Azarneshan (2014) found that the soil's dry bulk density increased with the increase in fertilization, whereas it remained same with no fertilization. Wang and Xing (2016) found the irrigation application to tomato crop based on 50 percent of ET_C increased 1.23 times the nitrate nitrogen content at the depth of 60 cm soil profile as compared to the 75 and 100 percent of ET_C.

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Cabbage (*Brassica oleracea* L.) belongs to the family cruciferae and is a good source of vitamin and minerals. In Pakistan, it is cultivated on 4936 ha area with an average annual production of 77311. Sindh is the second leading producer of cabbage after Punjab with the total cropped area and production of 1110 ha and 12210 tonnes (GoP, 2017). Very little information seems to be available on the effect of irrigation and nitrogen fertilization scheduling on the yield and yield parameters of cabbage, in the Sindh province. Furthermore, conventional methods of irrigation and fertilizer application is followed for this crop which often leads to poor plant population, non-uniformity in head size and lower yields. It is necessary for the vegetable growers to know how much water and when it should be applied to cabbage for enhancing its productivity? that can fetch good returns by increasing its marketability. Therefore, an effort has been made keeping all these in view to study the irrigation and nitrogen fertilizer scheduling on cabbage through raised bed irrigation with the objective to find out the optimum schedule of irrigation and nitrogen fertilizer for maximum cabbage yield, water use efficiency without damaging soil properties and nutrient deficiency.

MATERIALS AND METHODS

The field trial was performed at the experimental field of Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, located at $25^0$25′28″ N latitude and $68^0$32′26″ E longitude. The Randomized Complete Block Design (RCBD) procedure was adopted for arranging the trial with four treatments and three replications. The treatments i.e. T_1, T_2, T_3 and T_4 were application of irrigation and Urea fertilizer after 5, 15, 25 days and irrigation without fertilizer after 15 days respectively. The total area (36 m^2) was divided in to three blocks. Each block was further divided into four sub-plots of 9 m^2. The experimental soil was prepared by disc harrow, followed by cultivator and then leveled conventionally. The seed of cabbage (2.5 kg ha^{-1}) was sown on nursery plot for establishing seedlings. The cabbage seeds were treated before sowing with Vitavax @ 2.5 grams per kilogram of seed (GoP, 2005). Transplanting of seedlings from nursery to experimental plots was done 8-10 days after emergence. The seedlings were sown on raised beds. The raised beds were prepared manually. The top and bottom width of raised beds was kept as 0.45 and 0.76 m. The beds height and furrow width was kept at 0.25 and 0.45 m under all treatments. The spacing within the rows was maintained at 0.45 m and within plant 0.45 m. The schematic diagram of the raised beds is given in Figure 1.

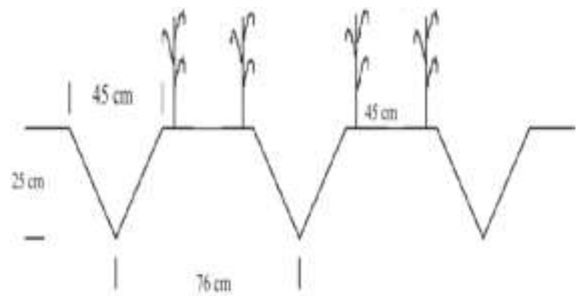

Figure 1. Schematic diagram of raised beds

The good quality groundwater was used for crop irrigation having electrical conductivity of 623 µS cm^{-1} and pH 7.5. In order to determine some soil properties and macro-nutrients, the soil samples were taken from top of the beds at the depths of 0-10, 11-20, 21-30 and 31-40 cm, before sowing and immediately after harvesting of the crop. The soil physical properties included soil dry bulk density, porosity and void ratio. The dry bulk density of the soil was determined by core method (McIntyre and Loveday, 1974). The formulations presented below were used to calculate the ρ_d, η and e values of the soil, respectively.

$$\rho_b = \frac{\text{Dry weight of soil}}{\text{Total volume of soil}}$$

$$\eta\,(\%) = \left(1 - \frac{\rho_b}{\rho_p}\right) \times 100\,(\%)$$

$$e\,(\%) = \left(\frac{\eta}{1-\eta}\right) \times 100\,(\%)$$

Where ρ_d stands for a dry bulk density of the soil (g/cm^3), η represents porosity of the soil in percent and e- signifies void-ratio of the soil in percent.The soil samples were sent to Agriculture Research Institute, Soil Chemistry Laboratory, Tandojam for the analysis of pH, EC_e, SAR, ESP, CO_3^{2-}, HCO_3^- and Cl^-. The soil pH and EC_e were determined by digital pH and EC meters. The exchangeable sodium percentage (ESP) and sodium adsorption ratio

(SAR) were calculated using the formula of the USDA (1954):

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

$$ESP = \frac{100(-0.0126 + 0.01475 \times SAR)}{1 + (-0.0126 + 0.01475 \times SAR)}$$

According to the Fresenius *et al*. (1988), titration method was adopted for determining the soluble Ca^{2+}, Mg^{2+}, CO_3^{2-}, HCO_3^- and Cl^- and EEL-Flame photometer was used for the analysis of sodium (Na^+).

The soil samples were also sent for macronutrients (NPK) analysis to Soil Laboratory of Nuclear Institute of Agriculture, Tandojam. The soil available total nitrogen (N) was determined by digestion with concentrated sulfuric acid (H_2SO_4) along with a mixture of Pumice grains, Copper sulfate ($CuSO_4$) and Potassium sulfate (K_2SO_4) using Kjeltech Digestion System. The soil available total phosphorous (P) was determined by digesting the soil samples in 1:5 Perchloric acid ($HClO_4$): Nitric acid (HNO_3) mixture, followed by analysis of the digest by vanadomolybdo phosphoric acid yellow color method (Barton, 1948). The soil available total potash (K) was determined by digesting the soil samples in 1:5 $HClO_4$: HNO_3 mixture, followed by analysis of the digest through flame photometer (Jackson, 1958).

The recommended dose of the chemical fertilizers (240-120-120 kg NPK ha^{-1}) was applied (Singh *et al*., 2013). The P and K were applied once before transplanting through di-ammonium phosphate (DAP) and sulphate of potash (SoP). As per the designed treatments, Urea in the form of N was applied in three splits (0.012, 0.036 and 0.054 kg $plot^{-1}$) under T_1, T_2 and T_3 treatments, whereas no any fertilization was done under T_4 treatment.

The irrigation was applied to the cabbage crop on the basis of designed treatments i.e. 5, 15 and 25 days interval and for the no fertilizer treatment the irrigation was applied at 50% depletion of the field capacity of soil which was estimated at 15 days. The required water depth was calculated using the equation given as under:

$$D = \frac{\text{SMD}}{100} \times \rho_d \times d_r$$

Where, D = depth of water required (cm), SMD = Soil moisture deficit level, = Dry bulk density (g cm^{-3}), = Root depth at the time of irrigation (cm). The field capacity of the soil was determined by core method (Veihmeyer and Hendricksen, 1931). The following formula was used to identify the soil moisture deficit level:

$$SMD = \theta_f - \theta_0$$

$$\theta = \frac{W_w - W_d}{W_d} \times 100$$

Where, SMD= Soil moisture deficit level, = Moisture content at field capacity (%), = Moisture content at 50% SMD, ϴ = Moisture content on dry weight basis, = Wet weight of soil (gm), = Oven dry weight of soil (gm). In order to determine the volume of water need to be applied, a cut-throat flume was installed at the head of field channel (Skogerboe *et al.*, 1972).

The data on plant height (cm) and yield $plant^{-1}$ (kg) were collected under all treatments with standard methods. The cabbage was harvested when the cabbage heads become hard. The cabbage heads from each treatment were collected and weighed. The collected data were subjected to statistical analysis by software package Statistix (Version 8.1).

RESULTS AND DISCUSSION

Soil physical properties

The data related to soil dry bulk density (ρ_d), porosity (η) and void ratio (e) pre-sowing of the crop and immediately post harvesting of the crop under different treatments are given in Table 1. The dry bulk density of the soil increased 0.056, 0.030, 0.016 and 0.010 g cm^{-3} under T_1, T_2, T_3 and T_4 treatments, respectively. The dry bulk density values increased in all treatments, however maximum increase was observed in T_1, followed by T_2, T_3 and T_4 treatments. This indicates maximum salt accumulation on the beds that was possibly due to the maximum number of irrigations and frequent fertilizer applications made under T_1 than T_2, T_3 and T_4 treatments. Yargholi and Azarneshan (2014) also found increase in soil dry bulk density with the increase in fertilization rate. The soils dry bulk density values differed significantly among treatments at the confidence interval of 95% (P<0.05).

The porosity (η) of the soil decreased to 2.1, 1.2, 0.6 and 0.4% and the void ratio (e) of the soil decreased to 6.41, 3.63, 1.83 and 1.22%

under T_1, T_2, T_3 and T_4 treatments, respectively. The porosity (η) and void ratio (e) decreased significantly (P<0.05) under T_1, followed by T_2, T_3 and T_4 treatments, respectively. This indicates maximum salt accumulation which might have replaced the pore space, possibly due to the maximum number of irrigations and frequent fertilizer applications made under T_1 than T_2, T_3 and T_4 treatments.

Soil chemical properties

The average results of the chemical properties of the soil i.e. hydrogen ion concentration (pH), electrical conductivity (EC), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP), carbonates (CO_3^{2-}), bicarbonates (HCO_3^-) and chloride (Cl^-) pre sowing of the crop and immediately post harvesting of the crop under different treatments are given in Table 2.

The pH of the soil was decreased by 0.06, 0.04, 0.02 and 0.02 under T_1, T_2, T_3 and T_4 treatments, respectively. For most of the crops 6.5-7.5 pH is an ideal range, where optimum solubility of most important plant nutrients is achieved (Murad, 2012). The significant (P<0.05) decrease in soil pH occurred under T_1, followed by T_2, T_3 and T_4 treatments (Figure 2). This was possibly due to frequent irrigation and nitrogen fertilizer applications under T_1 treatment, therein fertilizers applied get utmost opportunity to be dissolved, and owing to that, the maximum decrease in pH value occurred under this treatment. Bendi and Brar (2009) also reported that the use of synthetic urea fertilizer decreases the soil pH.

During the course of experiment, electrical conductivity values of soil seem to be increased by 0.18, 0.12, 0.08 and 0.05 dS m^{-1} under T_1, T_2, T_3 and T_4 treatments, respectively. Significantly (P<0.05) maximum increase was observed under T_1, followed by T_2, T_3 and T_4 treatments. This is quite logical, with the frequent irrigation and nitrogen fertilizer under raised beds planting; nitrogen or urea causes acidification and when water evaporates it leaves behind the salts on the top of the beds.

In raised beds, the salinity decreases in furrows and bed edges, while increases in bed centre (Devkota *et al.,* 2015). Since, the soil samples were collected from the centers of raised-beds, the EC values were found to be higher to that of initial values.

The SAR increased by 1.3, 0.7, 0.3 and 0.2; and ESP increased by 1.6, 0.9, 0.4 and 0.3 under T_1, T_2, T_3 and T_4 treatments, respectively. Obviously SAR and ESP values increased significantly (P<0.05) under T_1, followed by T_2, T_3 and T_4 treatments, indicating the highest content of exchangeable Na^+ in the soil under T_1 treatment due to the maximum number of irrigations and fertilization practices than its counterpart. The SAR and ESP values of the soil remained within the safe limit (<15) under T_3 and T_4 treatments except T_1 and T_2 treatments (Horneck *et al.,* 2007).

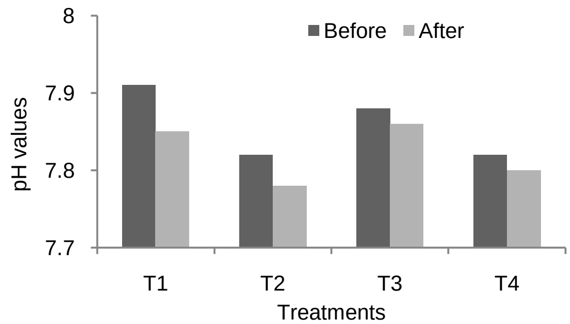

Figure 2. pH of soil before sowing and after harvesting of crop

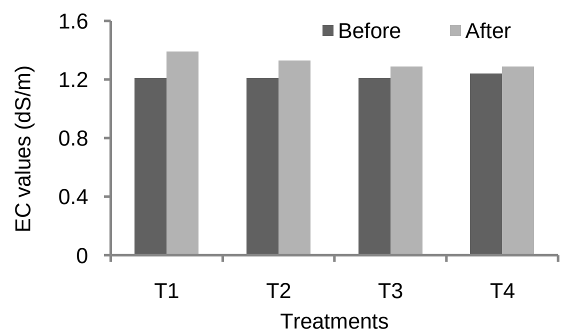

Figure 3. EC values of soil before sowing and after harvesting of crop

The CO_3^{2-} and HCO_3^- determined in the soil samples collected before sowing and immediately after harvesting were absent. According to Wang *et al*. (2015), CO_3^{2-} containing soil samples demonstrate a pH greater than 7.5. However, in the present study the pH values were found within the range of 7.78 to 7.91, close to 7.5. It can be concluded from these results that the CO_3^{2-} contained by soil samples may demonstrate a pH within the range of 7.5 to 8. The non-availability of HCO_3^- does not affect the scheduling of irrigation and fertilizer for growing cabbage crop. According to USDA (1954), the availability of HCO_3^- exerts specific toxic effects, resulting in serious injury even at low osmotic concentration. Bicarbonates affect the uptake and metabolism of nutrients by plants.

The concentration of Cl^- in the soil samples significantly (P<0.05) increased by 1.9, 1.2, 0.4 and 0.1 meq L^{-1} under T_1, T_2, T_3 and T_4 treatments, respectively. The result implies that the maximum increase in Cl^- content occur with the frequent irrigation and nitrogen fertilizer. According to BERSG (2005), the Cl^- limits of 10 to 79 meq L^{-1} are the range of tolerance of agricultural crops without compromising on the yield.

In general, the values of chemical properties increased with the frequent irrigation and fertilization, which is in close agreement to the results obtained by the Dubey *et al*. (2012), Saraswathy and Prabhakaran (2014) and Rizwan *et al*. (2016).

Macronutrients in the soil

The macronutrients status of the soil before sowing of the crop and immediately post-harvesting of the crop is presented in Table 3. The macro-nutrients of the soil i.e. nitrogen, phosphorous and potash increased significantly (P<0.05) under all treatments, except T_4 treatment. The nitrogen content increased by 2.3, 3.1 and 8.5 mg kg^{-1} under T_1; T_2 and T_3 treatments, however they decreased by 1.3 mg kg^{-1} under T_4 treatment. The phosphorous content increased 0.7, 0.9 and 1.7 mg kg^{-1} under T_1, T_2 and T_3 treatments, however decreased to 0.4 mg kg^{-1} under T_4 treatment. The potash content increased by 0.6, 4.9 and 7.2 mg kg^{-1} under T_1; T_2 and T_3 treatments however it decreased by 1.3 mg kg^{-1} under T_4 treatment. This is because of the frequent irrigation (5 days) under T_1 treatment, owing to that soils having maximum opportunity to leach out nutrients out of the root zone. Similarly, the soils under T_3 treatment (25 days) having minimum opportunity to leach out the nutrients as compared to T_2 treatment (15 days). Furthermore, no any fertilizer included in the soil under T_4 treatment and also available nutrients were used by the plants, thus the nutrients of the soils decreased as compared to the initial values.

Irrigation and crop parameters

The irrigation and crop parameters such as irrigation applied (Nos.), water used (m^3 ha^{-1}), yield (kg ha^{-1}), water productivity (kg m^{-3}), plant height (cm) and head weight (g) under T_1, T_2, T_3 and T_4 treatments are given in the Table 4. Depending on the designed treatments, the number of irrigations made varied under different treatments. The maximum quantity of water was used under T_1 (5 days) treatment, followed by T_2 (15 days), T_4 (15 days) and T_3 (25 days) treatments. This is because of the frequent irrigation applied under T_1 treatment, owing to that the evaporation and deep percolation losses from the soils would be higher than the other treatments.

Significantly highest cabbage yield of 22, 6 and 51% was found with T_3 (25 days) treatment over T_2 (15 days), T_1 (5 days) and T_4 (no fertilizer) treatments. This was possibly due to the better aeration in root-zone profile of the crop and maximum availability of nutrients under T_3 treatment, in which the irrigation and fertilizer was applied with an interval of 25 days. Rizwan *et al*. (2016) reported the over or under fertilization cause severe yield losses. Saraswathy and Prabhakaran (2014) reported that the indiscriminate use of chemical fertilizers leads to decline crop productivity. Gerami *et al*. (2016) found that the all agronomical variables of oregano increased with the increased irrigation interval. Sardrood *et al*. (2013) found lowest sorghum yield and Jigme *et al*. (2015) found lowest broccoli yield while no any fertilizer added to the soil. Mindari *et al*. (2015) found increase in exchangeable sodium, sodium adsorption ratio and dry bulk density which resulted in lower decrease in rice yield.

The highest yield and lesser water use under T_3 treatment increased the crop water productivity. The water productivity of the cabbage increased 45, 15 and 55% under T_3 treatment over T_1, T_2 and T_4 treatments. The agronomic parameters of the crop such as plant height and head weight, followed the similar fashion of yield and water productivity under T_3 treatment. The water used (m^3 ha^{-1}), yield (kg ha^{-1}), water productivity (kg m^{-3}), plant height (cm) and head weight (g) differed significantly under all treatments at the confidence interval of 95% (P<0.05).

Table 1. Soil physical properties

Parameters	Pre-sowing				Post-harvesting				Difference			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
ρ_d (g cm^{-3})	1.490	1.510	1.510	1.510	1.546	1.540	1.526	1.520	0.056a	0.030b	0.017c	0.010c
η (%)	43.80	43.10	43.10	43.10	41.70	41.90	42.50	42.70	2.10a	1.18b	0.60c	0.40c
e (%)	77.93	75.74	75.74	75.74	71.52	72.11	73.91	74.52	6.41a	3.63b	1.83c	1.22c

Table 2. Soil chemical properties

Parameters	Pre-sowing				Post-harvesting				Difference			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
pH	07.91	07.82	07.88	07.82	07.85	07.78	07.86	07.80	0.06a	0.04ab	0.02b	0.02b
EC (dS m^{-1})	01.21	01.21	01.21	01.24	01.39	01.33	01.29	01.29	-0.18a	-0.12b	-0.08c	-0.05c
SAR	14.05	15.02	13.09	14.04	15.8	15.9	14.2	14.6	-1.3a	-0.7b	-0.3bc	-0.2c
ESP	18.02	13.07	13	16	19.8	14.6	13.4	16.3	-1.6a	-0.9b	-0.4c	-0.3c
$CO3^{2-}$ (meq L^{-1})	--	--	--	--	--	--	--	--	--	--	--	--
HCO_3- (meq L^{-1})	--	--	--	--	--	--	--	--	--	--	--	--
Cl- (meq L^{-1})	12	13.1	11.7	12.3	13.9	14.3	12.1	12.4	-1.9a	-1.2b	-0.4c	-0.1d

Table 3. Soil macro-nutrients

Parameters	Pre-sowing				Post-harvesting				Difference			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Nitrogen (mg kg^{-1})	25.36	24.01	27.02	20.01	27.66	27.02	35.7	17.08	-2.3b	-3.1c	-8.5d	2.3a
Phosphorous (mg kg^{-1})	05.30	07.00	07.80	05.60	06.00	07.90	9.50	05.20	-0.7b	-0.9c	-1.7d	0.4a
Potash (mg kg^{-1})	13.50	14.90	16.60	12.40	14.10	19.80	23.80	11.10	-0.6b	-4.9c	-7.2d	1.3a

Table 4. Irrigation and crop parameters

Parameters	Treatments			
	T_1	T_2	T_3	T_4
Irrigations applied (Nos.)	18	06	04	06
Water used (m^3 ha^{-1})	5400a	4200b	3800c	4200b
Yield (kg ha^{-1})	8416b	10138a	10759a	5308c
Water productivity (kg m^{-3})	1.55c	2.41b	2.83a	1.26b
Plant height (cm)	21c	23b	25a	17d
Head weight (g)	176b	212a	225a	111c

CONCLUSION

Significant effect of different irrigation and fertilization schedules observed on yield, yield components, water productivity, and nutrients status and on physico-chemical properties of the soil. The soil dry bulk density increased with the frequent fertilization and irrigation. The soil pH decreased and ECe, SAR, ESP and Cl^- increased with frequent irrigation and fertilization scheduling. The cabbage was found to be water sensitive plant whose yield decreased with the over irrigation (frequent irrigation). The yield of cabbage increased 6-51% and water productivity increased from 15-55% with irrigation and urea fertilization scheduling of 25 days over the other schedules. Therefore, optimum schedule of irrigation and urea fertilizer for the cabbage was found as 25 days for December sowing season.

AUTHOR'S CONTRIBUTION

Nowsherwan: Conducted research.
S. A. Soomro: Supervised research.
B. Wagan: Supervised research.
N. Gul: Data analysis on interpretation.
I. A. Sheikh: Data analysis on interpretation.

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