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Potassium to nitrogen ratio favors photosynthesis in late-planted cotton at high planting density

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ABSTRACT

Late sowing of short growing season cotton, planted in high density with one time fertilization is a potential economic alternative for the conventional cotton growing practice in the Yangtze River Valley, China. The appropriate proportion of nutrients is indispensable for an economic crop production. Therefore, the present study was designed to explore the best relative ratios of potassium (K) to nitrogen (N), under a new short-season and high density planting model, based on the photosynthetic performance of cotton plants in relation with the yield. A two-year (2016–17) field experiment was conducted with three K relative ratios to N [0.8 (K08: 168 kg ha^{-1} K_2O), 1.0 (K10: 210 kg ha^{-1} K_2O) and 1.2 (K12: 252 kg ha^{-1} K_2O)]. The results indicated that K10 increased seed cotton and lint yield by 10–20% and 10–24%, respectively, over K08 and no difference was existed between K10 and K12. Similarly, K10 and K12 increased SPAD value by 3–10% and 11–18%, photosynthetic rate by 7–57% and 0.7–89%, and chlorophyll fluorescence parameters by 1–8% and 1–29%, respectively, as compared to K08. And the highest photosynthetic attributes were achieved for the 4th main stem leaf from the top at peak bloom (PB) stage. These results suggested that the K10 is the most suitable ratio as for cotton yield and economic concerns under the newly proposed planting model in the Yangtze River Valley, China.

1. Introduction

Cotton is the most important cash crop, grown for the purposeof oil, seed, lint, fiber, and animal meal all over the world (Constable and Bange, 2015). Worldwide, cotton is cultivated in more than 75 countries occupying more than 30 million hectares (Saranga et al., 2001). China is one of the leading cotton producers in the world with the average lint yield of 1438 kg ha^{-1} (USDA, 2013). Hubei, the major cotton growing province in China, contributes approximately 12.3% of the total national lint production in less than 9.4% of the planting area (Yang and Zhou, 2010). Despite the introduction of high yielding cultivars, cotton yield per unit area in this region is stagnant from the last several years (Yang et al., 2014). There might be several factors responsible for the stagnancy of cotton yield in terms of quality and quantity, such as improper sowing methods and time, unbalanced fertilization including nitrogen (N), phosphorous (P), and potassium (K), (Nasim et al., 2011) unfavorable weather conditions, and excessively high relative humidity at the time of boll opening (Khan et al., 2017b; Tung et al., 2018a).

Pre-requisites for a successful crop establishment is the proper field management and application of balanced inputs (Dai and Dong, 2014; Amin et al., 2017). Nutrients (especially NPK) are the important inputs having great significance for both profitable productivity and economic return. Among nutrients, K application and its balanced relative ratio to N is the most crucial factor for the crop productivity (Awais et al., 2017), especially for the cotton. It is an important inorganic cation in plants, having a substantial role in several physiological, biochemical and metabolic processes. It is involved in the maintenance of osmotic potential, cytoplasmic pH homeostasis, charge balance, enzymes activation, photosynthates translocation, stomatal regulation and water uptake (Oosterhuis et al., 2014). Photosynthetic metabolism requires appropriate concentrations of potassium for the proper functioning (Marschner and Marschner, 2012). The leaf net photosynthetic rate, stomatal conductance, photosynthetic phosphorylation activity, electron transfer energy, and the activity and contents of Rubisco were reported to be significantly affected by K in rice (*Oryza sativa* L.), cotton (*Gossypium hirsutum* L.), and maize (*Zea mays* L.) (Zhao et al., 2001; Wang et al., 2012).

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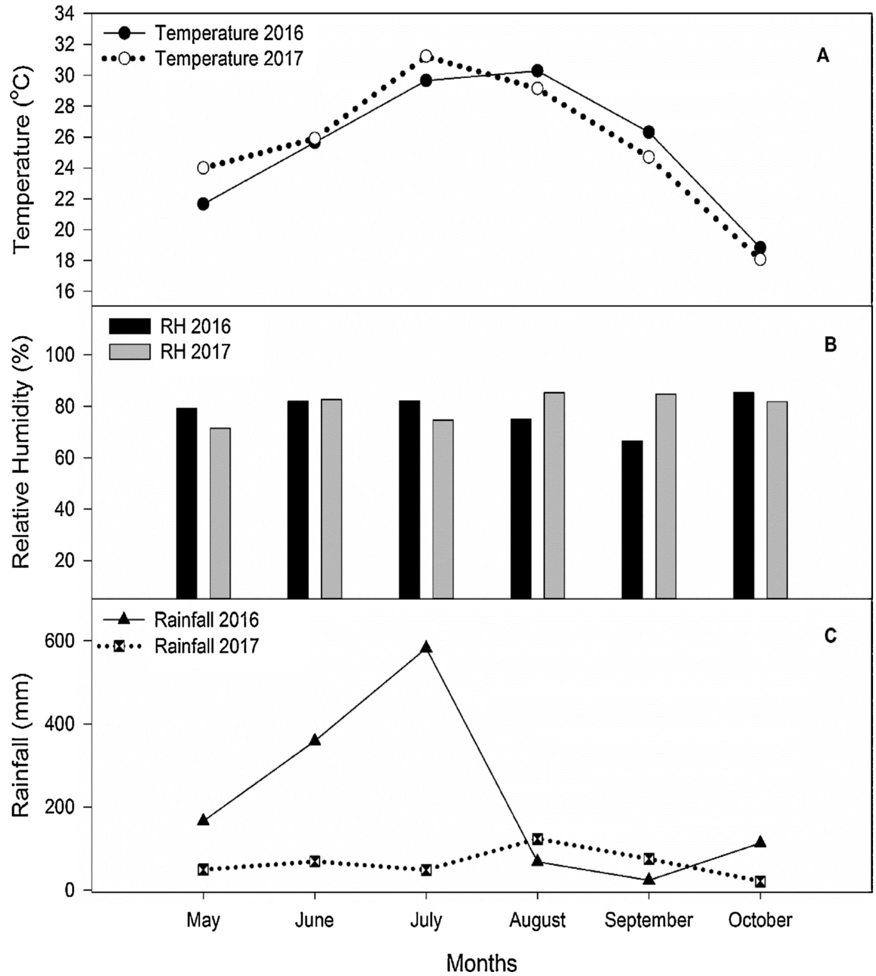

Fig. 1. Weather conditions of 2016 and 2017 during crop growing season (a) temperature (°C), (b) relative humidity (%), (c) total rainfall (mm).

Photosynthesis, the most important physiologically sensitive process influencing a plant's metabolism and development, is a critical factor in plants productivity and is directly related to the crop yield (Liu et al., 2015). Several morphological, physiological, and biochemical factors are involved in the plants photosynthesis. Chloroplast ultrastructure and chlorophyll, an essential component of a plant cell for converting light into usable chemical energy, are important constituents of the plants photosynthetic system (Hu et al., 2016b). Photosynthesis in plants greatly relies upon the photochemical processes including the chlorophyll fluorescence, an important indicator of the photosynthetic energy conversion during light reaction (Liu et al., 2015). Biochemical factors such as photosynthetic phosphorylation, electron transfer energy, contents and activity of Rubisco, sucrose synthase (SuSy), sucrose phosphate synthase (SPS) and other saccharides forming enzymes, are also involved directly or indirectly in the regulation of photosynthesis (Liu et al., 2013; Ali et al., 2018). All of these factors along with the plants photosynthesis, significantly contribute towards cotton yield (Pettigrew et al., 2005; Wang et al., 2012) by enhancing crop growth rate, dry matter assimilation, and its translocation towards reproductive organs. However, crop yield depends upon a number of complex physiological and morphological factors. The seed cotton yield formation does not rely only on plants photosynthesis but is also dependent upon the effective translocation and partitioning of photo-assimilates to the reproductive organs (Liu et al., 2015; Wang, 2007) to fetch the higher crop yield.

Several factors, including high input cost of cotton production, less profitability, long lifespan and its interference with the wheat growing season discourages farmers of Yangtze River Valley to further continue the cotton cultivation. The conventional N rate for cotton in this region is 300 kg ha^{-1}, usually applied in three splits (Yang et al., 2011). The normal farmer's practice for K application is in two splits (50% for each of pre-planting and first bloom stage) and ratio ranges from 0.6–0.8 (180–240 kg ha^{-1} K_2O) relative to N (300 kg ha^{-1}) in the growing region. Presently, applied K ratio has been proved to be inadequate for the optimum crop yield (Yang et al., 2011).

After a series of experiments, we have developed a new short season, economically sound, cotton planting model that could retain, convince, and encourage farmers for the cotton production in the Yangtze River Valley. The new planting model comprises shorter growing season (160–180 days), late sowing (up to mid of May), high planting density (90,000 plants ha^{-1}) (Khan et al., 2017a; Yang and Zhou, 2010), reduced N fertilizer application rate (Yang et al., 2011), one-time fertilizer application (at the time of first flower appearance in the field) (Yang et al., 2012; Tung et al., 2018a), and decreased plant height (Tung et al., 2018b). This model is practically feasible and economical as it reduces the inputs and cuts the labor cost, without compromising yield attributes. However, to further reduce the production cost and to attain maximum productivity in a resource efficient manner, optimization of relative K ratio to N is indispensable. Thus, we hypothesized that the relative change in K ratio to N may affect the photosynthesis of cotton that could affect the overall productivity under late sowing and high planting density.

Keeping in view the importance of potassium and plant photosynthesis for the growth and overall productivity, the present study was conducted with the objectives; (1) to explore the best relative ratio of K to N for the effective photosynthetic activity of cotton plants to attain