**Research Proposal**

**Title: Integrated effect of plastic film mulch and P fertilization on linseed (*Linum* usitatissimum L.) productivity and soil properities under semi-arid conditions**

**Duration: 03 years**

**Abstract**

Linseed (*Linum* usitatissimum L.) is an imperative oil seed crop however its yields in dry land farming areas are usually very low due to water shortages and low soil phosphorus (P) availability. This study assessed the effects of plastic film mulch and P fertilization on linseed yield and shoot P uptake in response to improved soil moisture and soil P availability in a dry land farming system of northwest China. The experiment will be laid out in Randomized Complete Block Design (RCBD) with split-plot arrangement and each treatment will be replicated four times. The experiment will be comprised of two mulch treatments (a) plastic film mulch with ridge and furrow (PFM) (b) no plastic film mulch with flat planting (NPFM) as main plots, and four P levels (0, 10, 20 and 30 kg P ha-1, hereafter referred to as P0, P1, P2 and P3, respectively) as split plots. Data collected on various growth and yields components, shoot P concentartion, soil available P, soil moisture, water use efficiency (WUE), soil microbial biomass P (MBP), activities of acid and alkaline phosphatase (ACP and ALP, respectively) will be analyzed statistically by using the Statistix 8.1 software analysis of variance technique and significant of treatment means will be tested using Tukey’s (HSD) test at 5% probability level.

1. **Scientific background**

Linseed (*Linum* usitatissimum L.), as an oilseed crop, has been planted for over two thousand years in China (Mo et al., 2018). In 1990s, the planting area had grown rapidly owing to increased demand of linseed products by industrial revolution (Heller et al., 2015). After 2000, there was a tendency to decrease linseed planting area, mainly because of low seed yield and reduced demand. Linseed oil is primarily used for food and medical purposes and considered as functional food due to the high level of omeg-3 fatty acid and alpha-linolenic acid in seeds (Dixit et al., 2012). In the last several years, food safety and health concerns have renewed the interest of policy makers to enlarge the planting area of linseed flax again (Heller et al., 2015). In 2012, the planting area of flax was up to 0.3 million hectares in China, and more than 50% of them was in the Loess Plateau including Gansu, Shanxi, Inner Mongolia, Ningxia and Qinghai provinces (Mo et al. 2018).

Phosphorus (P) is the second most important essential macronutrient vital for crop growth and soils are usually supplemented with P in the form of chemical fertilizers (Ahmad et al. 2013). In the semiarid Loess Plateau of Northwest China, P fertilizer has been applied extensively since 1980 to increase crop yields (Li et al., 2004). P is an essential nutrient in soil that limits plant growth and metabolism due to its low mobility and bioavailability (Lægreid et al., 1999). However, the availability of P fertilizer to crops is usually very low, with up to 80% of the applied P fertilizer fixed in the soil as recalcitrant organic and adsorbed inorganic forms, which limits crop growth and requires high P fertilizer use in the long term (Olander and Vitousek, 2005). Even so, external P additions increased shoot and root biomass in cowpea (Alkama et al., 2009). In general, P availability in soil is determined by the competition between geochemical sorption and biological sinks (Richardson and Simpson, 2011; Zhang et al., 2014). Negatively charged inorganic P (H2PO4- and HPO42-) is usually absorbed to positively charge mineral and organic particles (Richardson and Simpson, 2011). Iron and aluminum ions in acid soil and calcium (Ca) ions in alkaline soil interact strongly with inorganic P to form iron, aluminum or Ca phosphates, so-called P precipitation (Jungk et al., 1993; Spohn and Kuzyakov, 2013). Organic forms of soil P are absorbed, incorporated within biomass, or associated with soil organic matter (Richardson and Simpson, 2011). Both inorganic P (including absorbed P and precipitated P) and organic P in soil contribute to the P nutrition of plants and microorganisms (Jungk et al., 1993).

In a field experiment on a luvisol, organic P dissolved in soil solution by phosphatase contributed one-third of the P uptake in barley (Jungk et al., 1993). Soil microorganisms not only solubilize and mineralize P, but they can reduce P bioavailability by P immobilization in microbial biomass (Spohn and Kuzyakov, 2013). Plant and soil microbial P solubilization and mineralization processes coincide in the soil, and thus compete for inorganic P under P-limited conditions; this is regulated by the ratio of soil organic carbon (SOC) and available phosphorous (AP) (Zhang et al., 2014). In general, microbes contribute to plant P uptake when the soil C:P ratio is less than 200 but compete with plants for P when the ratio is more than 300 (Stevenson and Cole, 1999).

Plastic film mulch increases soil microbial activity by improving soil water and temperature conditions and producing more crop biomass (Li et al., 2004; Wang et al., 2016), which would increase soil nutrient availability (Wang et al., 2017). Soil water and P availability are crucial for linseed growth, but research on the effect of plastic film mulch on P availability in semiarid regions is scarce. The present study investigated with the following objectives.

1. **Research objectives**
* To assess the effects of plastic film mulch and P fertilization on linseed growth and yield components, water use efficiency and shoot P concentration.
* To determine the responses of soil water content and soil P availability to plastic film mulch and P fertilization.
* Whether soil P availability is affected by soil pH or phosphatase activity.
1. **Tentative Research Program**

**1.1 Experimental design and field management**

The experiment will be laid out in Randomized Complete Block Design (RCBD) in a split-plot arrangement and each treatment will be replicated four times. The treatments included two mulch practices (a) plastic film mulch with ridge and furrow (PFM) (b) no plastic film mulch with flat planting (NPFM) in main plots and four P levels (P0 = 0, P1 = 10, P2 = 20 and P3 = 30 kg P ha-1 in split plots.

**1.1.1 Field Managment**

Before sowing 34.5 kg N ha-1 and half of each corresponding P level will be broadcast and ploughed into the top 20 cm of each plot. No other fertilizers will be applied to the soil apart from P fertilizer in the experimental years. The ridges (30 cm wide × 15 cm high) will be functioned as rainwater harvesting zones. The furrows will be a V type (width = 0) and act as linseed planting zones. Three ridges will be cover with a 1.2 m wide plastic film (0.008 mm thick polyethylene film) using a tractor, the local linseed cultivar ‘XXX’ will be sown at seedling density of 60 kg ha-1 in all plots each year. Each plot will be 4.4 m long and 4.4 m wide, and each treatment will be replicated four times. The experimental field will resemble a terrace, with the ridges built between adjacent plots to prevent runoff. Throughout the growing season, weeds will be control manually and disease-pest management will apply to maintain healthy crop growth. For each plot, the harvesting will be perform at maturity

**1.2 Data collection**

**1.2.1 Final plant height and growth components**

The height of plant in each treatment will be measured in centimeters from the soil surface to the top of the apex with the help of meter rod. The total numbers of leaves will be counted at flowering stage for each treatment plant. Leaf area (cm2) will be measured in cm2 with the help of leaf area meter just after the complete emergence of panicle.

**1.2.2 Yield components and grain yield**

At maturity, yield components including capsule number per plant, fertile and unfertile branch number per plant will be measure by randomly selecting 30 plant individuals in each plot. The linseed number will also count by randomly select 30 capsules in each plot. Plot linseed yield will be determined by harvesting all the plants in each plot, shelled by machine and air-dried. Four repeated measurements on 1000-seed weight will be completed for each plot.

**1.2.3 Shoot P concentration**

The oven-dried plant stem will be ground to a fine powder using an Ultra centrifugal mill. The shoot P concentration will be determined using the molybdenum-antimony anti-spectrophotometric method (Ren et al., 2011) after digestion with H2SO4–H2O2 (Thomas et al., 1967). The P budget will be estimated by subtracting the P removed from the system by the aboveground linseed yield from the P applied as mineral fertilizer (Oberson et al., 2001). The physiological P use efficiency (PPUE, kg2 g-1 ha-1) will be calculated as the ratio between aboveground linseed yield and shoot P concentration (Hammond et al., 2009).

**1.2.4 Soil moisture and water use efficiency (WUE)**

The soil gravimetric water content (GWC, %) will be determined at a depth of 1 m with each 0.1-m interval on the 28th of each month. In each plot, soil samples will be taken by using a 0.08 m diameter portable auger for three random sampling points in the middle part between two plants in the rows. The spatial and temporal changes in soil moisture will eventually evaluated by soil water storage (SWS, mm). The SWS will be calculated according to the following formula:

SWS (mm) = GWC (%) × ρb (g cm-3) × SD (mm)

Where ρb is soil bulk density in each soil layer and SD refers to as soil depth.

Water use efficiency (WUE) will be calculated as the ratio of annual total linseed yield to the sum of total rainfall during the linseed growing season and the difference in SWC in the upper 1 m soil profile between the beginning and end of the growing season.

**1.2.5 Soil properties**

The each collected soil sample, consisting of three sub-samples from ridge soils and three from furrow soils (each 8 cm in diameter and 20 cm in depth), will be pass through a 2 mm mesh sieve. The sieved soil samples will be divided into two parts: one was stored at 4 °C for determination of soil microbial biomass P (MBP) and the activities of acid and alkaline phosphatase (ACP and ALP, respectively), and the other will be air-dried for pH, AP and SOC determination. Soil pH will be measure by using pH meter. Soil AP will be determined using the Olsen-P method (Olsen et al., 1954). SOC will be determined by the Walkley and Black dichromate oxidation method using a factor of 1.3 (Hai et al., 2010). MBP will be estimated with the chloroform fumigation-extraction method (Brookes et al., 1982). Phosphatase activities will be determined according to Tabatabai and Bremner (1969) and expressed as mg PNP kg-1 soil h-1. All calculations will be expressed on an air dry basis.

**1.3 Statistical analysis**

The data collected will be analyzed statistically by using the Statistix 8.1 software analysis of variance technique and significant of treatment means will be tested using Tukey’s (HSD) test at 5% probability level (Steel et al., 1997). The graphical representation of the data will be performed by using Sigma Plot 11.0 software.

1. **Expected achievements**

An appropriate combination of plastic film mulch and P fertilization will be determine that helpful to improve soil water condition and soil P availability for increased linseed yield or shoot P uptake under semi-arid region. Moreover, farmers will be able to cultivate other cash crop with this techniqe that will increase the livelihood of rural community which ultimately contribute in the economic growth of the country.

1. **References**

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