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GN Gurjar
Ph.D. research scholar at School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Vishram Ram
Professor (Farming Systems Research) at School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Sanjay Swami
Associate Professor (Nutrient Management) at School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Correspondence
GN Gurjar
Ph.D. research scholar at School of Natural Resource Management, CPGSAS, Central Agricultural University, Umiam, Meghalaya, India

Effect of organic mulches and planting date on soil chemo-biological properties and economics of rice-potato system in Meghalaya: A review

GN Gurjar, Vishram Ram and Sanjay Swami

Abstract
Planting date has significant effect on potato growth and yield. The aim of this work will to assess the response of chosen potato cultivars to temperature during the different stages of plant growth under conditions of different sowing dates and mulching practices. Mulches modify hydrothermal regime, recycles plant nutrients, promote crop development and increase yield. Mulching can be an effective technique to reduce soil evaporation. Paddy straw is easily available in North India during November-December and its an eco-friendly source of organic mulch. It is the cheap and benign technology for rural farmers. It also conserve soil moisture, maintaining a favourable soil moisture regimes by reducing evaporation loss from soil.

Keywords: organic mulch, potato, planting date, temperature, chemo-biological

Introduction
Potato (*Solanum tuberosum* L.) is the fourth most important food crop in the world, after corn, rice and wheat (FAOSTAT, 2016) [20]. For 2020, annual growth rate of potato production is projected to be higher than other major food crops. In the context of developing countries, potato will be key in addressing serious issues of food insecurity (Scott *et al*., 2000) [54]. It is grown in more than 100 countries, mainly in Asia and Europe. The potato is a plant mainly of typical temperate climate. The crop grows best in cool but frost-free seasons and does not perform well in heat. Rice and Potato both are the most important food crops of the north east India. Potato is the third crop next to rice and wheat in India (Haq and Matin, 2006) [24]. Mulches has positive impacts on water use and nutrient availability to plants. Plant growth at delayed planting significantly reduced the vegetable growth of the potato plant because of lower temperatures in the end of October and earlier November. Delayed planting reduced the yield of potato. Plant dry bio-mass production higher by planting the potato earlier. The physiological causes that led to yield reduction in delayed planting of potato had not been reported from Asian countries. Therefore, an attempt will under taken to analyse the growth, development indices of different potato varieties and yield of potato in relation to planting date (Ahmad *et al*., 2017) [3]. Rice is the most widely consumed staple food for a large part of world's human population, especially in Asia. It belongs to the genus oryza of gramineae family and has two cultivated and 22 wild species. In World, rice is grown in an area of 162.7 M ha with total production and productivity of 741 M t and 4.55 t ha^{-1}. In India, rice accounts for 43 percent of total food grain production and 55 percent of cereals production. It is grown in an area of 44.0 M ha with total production and productivity of 106.5 M t and 2.4 t ha^{-1}. Rice is the principal food crop of North Eastern Region of India. In Meghalaya, rice occupies an area, production and productivity of 1.04 lakh ha, 2.80 lakh tonnes and 2.55 t ha^{-1}, respectively (DES, 2015) [16].

Meghalaya is basically an agricultural state with about 80% of its population depending entirely on agriculture for their livelihood. Nearly 10% of the geographical area of the state is under cultivation. Agriculture in the state is characterized by limited use of modern techniques associated with lower yields and productivity. Potato (*Solanum tuberosum* L.) is characterized by specific temperature requirements and develops best at about 20°C. High temperatures during the growing season because an array of changes in potato plants, which affect its development and may lead to a drastic reduction in economic yield. Under high temperature, alteration in enzyme activities associated with carbon metabolism, starch accumulation, and

sucrose synthesis is caused by down-regulation of specific genes responsible for the same (Ruan *et al*., 2010) [51]. Ri-Bhoi being one of components of the Meghalaya plateau with almost similar physiographical features as in Khasi Hills. It's agriculturally important district with diverse farming systems. Soil-fertility depletion in smallholder farms is the main biophysical process explaining the decline in per capita food production. At farm scale, however, it becomes evident that the set of processes leading to soil fertility depletion is not homogeneously distributed in space. Variability in soil fertility arises from differences in underlying geology and geo-morphology, and due to a number of mechanisms within the farming systems (i.e. farm management practices). Farmers manage several organic and mineral resources in order to attain their production goals. With reduced assimilate production, high temperature above 20 °C interferes with assimilate partitioning in potato resulting in lower tuber yield (Ahmad *et al*., 2011) [2].

The aim of this work will to assess the response of potato to temperature during the different stages of plant growth under the micro climate attention with different sowing dates and mulching practices. The effects of mulching on soil moisture depend on precipitation and climatic factors. Mulching favourably influences soil moisture regime by controlling surface evaporation rate in winter and summer, mulching conserves soil moisture by reducing the evaporation rate. Mulches improve soil-moisture retention capacity as well as soil structure and suppress weed growth (Mutetwa and Mtaita, 2014) [44]. The soil-moisture variation is not, however, same under different mulching materials. The amount of soil-moisture conservation under different mulching materials differs in different soil types and climatic conditions. In general, the mulching treatments store higher soil moisture compared to the bare soil i.e. without mulch (Zhao *et al*., 2012) [62]. Application of organic mulches decreased the soil temperature as it creates barrier for penetration of solar radiation to soil surface that will be favourable for tuber bulking at later stage. Paddy straw is easily available in North India during November-December and it's an eco-friendly source of organic mulch. It is the cheap and benign technology for rural farmers. It also conserve soil moisture, maintaining a favourable soil moisture regimes by reducing evaporation loss from soil. Rice is a core cash crop and staple food in many Asian countries (Rao *et al*., 2007; Kumar and Ladha, 2011) [50, 35]. The biological and chemical properties of soils play an essential role for the regulation of organic matter decomposition, carbon sequestration and nutrient mineralization that are crucial for soil health.

1. Thermal behaviour of potato as influenced by sowing time

Bisognin *et al*. (2017) [7] studied to determine the thermal sum of the different stages of development of potato plants to better understand its relationship with tuber sprouting.

Hu *et al*. (2017) [26] showed that although delayed sowing shortened the duration of potato growth period, non-significant thermal time differences after flowering stage was found among the treatments.

Lehar *et al*. (2017) [37] found that the organic mulches with rice straw as increased the soil temperature as 28.06°C (July), 28.09°C (August), 29.32°C (September), 30.05°C (October) and reduce temperature during 20.98°C (July), 21.19°C (August), 21.21°C (September), 22.08°C (October).

Paul *et al*. (2017) [48] reported that the temperature induced abnormalities in vascular tissues appears to critical for tuber bulking rate and tuber yield (42–55% in the high yielding cultivars and 44–54% in the local cultivars). The cultivars that could maintain xylem size and phloem structure tended to minimize the negative effects of high temperature on tuber yield.

Davari (2016) [15] stated that the mulch play a significant role to regulate the temperature of soil by reducing the daily range and creating more constant temperature suitable for root activity. The ability of organic mulches to regulate the soil temperature is closely correlated with its ability to reduce evaporative water loss

Jamro *et al*. (2015) [29] stated that the overall results for tuber yield showed that TPS-9804 genotype planted on 30th October produced maximum tuber yield (29.46 t ha^{-1}) as compared to rest of genotypes; hence, TPS-9804 genotype is recommended for raising of TPS nursery with 30th October of planting date.

Hancock *et al*. (2014) [23] showed that the exposed tuber potato plants to mildly elevated temperatures (30/20 °C, day/night) for upto 5 weeks and compared tuber yield, physiological and biochemical responses, and leaf and tuber metabolomes and transcriptomes with plants grown under optimal conditions (22/16 °C). Growth at elevated temperature reduced tuber yield despite an increase in net foliar photosynthesis. This was associated with major shifts in leaf and tuber metabolite profiles, a significant decrease in leaf glutathione redox state and decreased starch synthesis in tubers. Furthermore, growth at elevated temperature had profound impact on leaf and tuber transcript expression with large number soft transcripts displaying arrhythmic oscillation at the higher growth temperature.

Dua *et al*. (2013) [18] estimated that rise in temperature alone will result in change in productivity of Kufri Badshah from +11.6% (Amritsar) to –10% (Fatehgarh) in 2020, whereas the change in productivity of Kufri Jyoti will be from +11.6% (Amritsar) to –11.6% (Fatehgarh) and of Kufri Pukhraj from +12% (Amritsar) to –11.5% (Mansa).

Li *et al*. (2013) [38] reported that the organic mulch dampens with the influence of environmental factors on soil by increasing soil temperature and controlling seasonal fluctuations of soil temperature.

Eruola *et al*. (2012) [19] found that grass mulch significantly ($P < 0.05$) lowered maximum soil temperature by 1-2 ^{0}C at 15 cm depth during the critical thermal period (January - March).

Novak *et al*. (2011) [46] stated that organic mulch or mulch made from plant residue, that entirely covers the surface of the ground would protect the ground from intensive rainfall and high temperatures.

Dam *et al*. (1996) [14] states that the photoperiod did not affect absolute tuber growth rate at lower temperatures. However higher temperature and longer photoperiod gave lower relative rates of partitioning of dry matter to the tubers.

2. Effect of organic mulch on its mineralization and soil moisture depletion pattern

Davari (2016) [15] reported that the organic mulches have the advantage of being biodegradable, but decomposition may result in a temporary reduction in soil mineral nitrogen. As inorganic nitrogen immobilized in the soil and it act as substrate in microbial decomposition of mulch's.

Hernandez *et al*. (2016) conducted an experiment with 3 different organic mulches (pine bark, cereal straw and palm leaf) in 2 different soils (loam and silty loam) and reported that the palm leaf was as effective as the cereal straw, so it is considered appropriate for use as a mulching material in areas

where its abundance and ease of use provide further environmental benefits.

Abouziena *et al*. (2015) [1] said that the mulching reduces the fluctuation of soil moisture and soil temperature.

Saha and Gosh (2010) [52] reported that the moisture extraction was maximum (32.2 to 44.5%) from 0–15 cm soil depth irrespective of crop combinations, and mulch treatments and it also decreased with soil depth. Increased water uptake by the crop from surface layers due to availability of surface soil moisture by mulch treatment may be the possible reason for such increase in moisture extraction pattern. Most of the soil water (65–75%) was extracted by the crop from the top 30 cm soil depth.

Bittelli *et al*. (2008) [9] stated that the changes of soil moisture in the upper surface layer (0– 10 cm) are highly dynamic due to water vapour fluxes across the soil-atmospheric interface.

Huang *et al.* (2008) [27] reported that application of organic mulch not only moderating soil moisture and temperature, but mulch residue also affects the dynamics of soil organic matter by decomposition of plant material applied to the soil. It increased soil nutrients after decomposition under appropriate water and temperature levels (Scott, 2007) [53].

Munda *et al*. (2006) [43] revealed that the effective management of crop residues, jungle grass, stubbles and weed biomass can have a beneficial role as mulching materials in moisture conservation practice and also as source of organic matter and plant nutrients in soil fertility. Further organic mulches has significant impact as can augment dissolved organic carbon (C) and nitrogen (N) by decomposition of plant materials (Chantigny, 2003) [12].

The soil moisture storage capacity increased with straw mulch over other mulching materials (Begum *et al.*, 2001) [5]. It add nutrients to the soil when decomposed by microbes, help in carbon sequestration and work as fertilizers after use (Ning and Hu, 1990) [45]. Organic mulching are more effective for moisture conservation and provide confined situation for crop growth and development as compared with plastic mulching with its additional soil building capacity (Khan *et al*., 1988) [33].

3. Chemical and biological pools of soil and its relationship with mulching and thermal responses

Wang *et al*. (2016) [60] found that the higher soil temperature under mulching promotes soil microbial activity and speeds up decomposition of organic matter in the soil. The increased organic matter will helps in increased cation exchange capacity of the soil which results in increased soil electrical conductivity (Chen and Weil, 2010) [13].

Jordan *et al*. (2010) reported that the mulches reduce deterioration of soil quality by preventing runoff and reducing soil loss that improves soil aeration, soil structure, organic matter content and physical properties of the soil. Also, the increased rate of mulch application increases soil porosity, improves aggregate stability and organic matter content, and reduces soil bulk density. Further reported that colour and type of mulching material also has positive impacts on moisture and temperature leads to control soil microbial properties (Moreno and Moreno, 2008) [41]

Subrahmaniyan *et al*. (2006) [58] reported 2, 12 and 12% increased population of soil bacteria, fungi and actinomycetes, respectively compared to the non-mulched treatment. In addition, the functional diversity of both microbial biomass and microbial community plays a role in plant litter decomposition and carbon cycling in forest ecosystems (Carney and Matson, 2005) [11] and increased soil fauna that improve the soil structure and quality (Doring *et al*., 2005).

As well as maintaining soil fertility by improving chemical properties of soils (Lumbanraja *et al.*, 2004) [39]. Lal (1998) [36] reported that the organic mulches enhances the soil biotic activities of earthworms. Further decomposition of organic mulches increased soil nutrient and leads to increased bacterial population (Mukhejee *et al*., 1991).

4. Economics of rice-potato system

Biswas (2017) [8] conducted an experiment to find out alternative remunerative cropping systems in comparison to existing rice-rice and rice-wheat system through crop diversification and reported that the Jute–potato-rice system paid the highest returns of US $1748 ha^{-1} and 1402 ha^{-1} during 2013-13 and 2013-14, respectively. High production cost related to high gross return, net return and return per dollar invested in jute–potato–rice, rice–potato–rice and rice–potato–sesame cropping systems, making them suitable for resource-rich farmers.

Pandiaraj *et al*. (2017) [47] reported that the rice-potato-maize(CS_3) sequence was found to be the most remunerative to the farmers with a net return of US$ 4250 ha^{-1} as compared to rice-vegetable pea-green gram (CS_2)(US$ 3429 ha-1), the B:C ratio was higher in CS_2 (4.01) followed by CS_3 (3.73).

Farrag *et al.* (2016) [21] conducted an experiment in split plot, consisted of three irrigation levels as main plots and three soil mulches as sub-plots with three replicates. Drip irrigation was practiced at 50, 75 and 100% of irrigation requirements (IR). The soil mulches consisted of black (PE-B) and transparent (PE-T) polyethylene as well as rice straw (RS). The use of PE-B mulch resulted in significantly higher values of plant height, number of leaves, and canopy fresh and dry weight per potato plant. Increasing IR of potato from 50% to 100% enhanced total and marketable yield.

Sharma *et al.* (2015) [55] revealed that rice-potato-onion, rice - garlic and rice-radish-potato cropping sequences were more remunerative resulting in significantly higher rice equivalent yield (16342, 10997 and 12394 kg/ha/annum, respectively), net returns (INR 153257, 102767 and 106414/ha/annum), productivity and profitability.

Saha and Gosh (2010) [52] reported that the highest net returns (Rs.56730) was recorded in rice-tomato/garden pea, followed by rice-potato/garden pea (Rs.51465).

Barman *et al*. (2008) [4] reported that the yield of potato increased to 1.81, 1.82, 2.06 and 2.89 times in metribuzin alone (T_7), earthing (T_2), rice straw mulch (T_4) and water hyacinth mulch (T_3), respectively. Also said that the pooled data showed there was 40.5% increase in potato yield in water hyacinth compared to rice straw mulched plots.

Rahaman *et al*. (2004) [49] reported that the benefit cost ratio was found to be highest (2.51) in rice straw followed by water hyacinth (2.46), wastes of rice straw (2.08) and no mulch (1.69). The results indicate that potato could be cultivated in saline soils with the application of rice straw mulch.

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