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A review on agronomical aspects of potato production in north-eastern region of India

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ABSTRACT

Besides more cropping intensity, per capita consumption of potato in the north eastern region is also four times higher than national average. In contrast to requirement, productivity of the same region is almost half of the country which highlights the significance of the crop. The climatic condition of hilly regions belong to the part of Eastern Himalaya of the country is quite suitable for growing more than one crop of potato throughout the year by selecting altitudinal variation. Hence, improving potato productivity is a key importance for farming community of north-eastern region. Efforts have been made to bring to light the previous research in this region and formulating future strategies to reduce the gap between potential and actual yield of potato crop in the land lock region of country. Further, the detection of the limiting factors that could be manipulated to increase productivity of potato is the major goal of such review. An overall examination of the climatic condition, soil fertility, quality seed, method of planting, integrated nutrient management, biofertilizers, potato based cropping system, scope of organic farming, weed management and plant protection measures are presented in this review.

Key words: *Biofertilizers, Cropping System, NEH Region, North East, Organic farming, Potato.*

I. Introduction

Potato (Solanum tuberosum) is an important food crop of the world. It is used as vegetable, stock feed and in industries for manufacturing starch, alcoholic beverages and other processed products. It is a highly nutritious food. It contains 20.6% carbohydrates, 2.1%protein, 0.3%fat, 1.1% crude fiber and 0.9% ash. It also contains good amounts of essential amino acids like leucine, tryptophane and isolucine [1]. Potatoes yield about 97 Kilo calories per 100 gm fresh weight, which is much than cereals. Potato being a short duration crop gave ample and economical tuber yield in 75 -80 days. This flexibility in growing period makes it highly amenable to adjustment in cropping systems without sacrificing acreage and minimal or no loss in yield of crops [2]. The North Eastern hill region of India covers 9% area of the country with 4% of its population. In this region potato productivity is very low (8.64 t ha-^{1}) except Tripura (17.3 t ha^{-1}) due to use of unscientific production technology [3]. The potato crop forms an important part of prevailing cropping systems as well as the dietary food habits of the people of the region [4]. Potato plays a vital role in food security for ever increasing world population [5], [6], [7]. It is highly capital and labour intensive crop [8]. Potato is an important crop in the North Eastern Region in India especially the hilly tracts, where the crop is grown under rain fed conditions [9]. The area under potato in this region as a percentage of the net cropped area is about four times the national average [10]. Potato is also an important crop among the horticultural crop in the North Eastern region of India comprising the states of Assam, Arunachal Pradesh, Mizoram, Nagaland, Manipur, Meghalaya, Tripura and Sikkim occupying about 10% of potato acreage and contribution of 4% of the total production in India [11]. The state of Assam has the maximum area and production under potato crop within the North East.

The highest productivity of this crop in the NEH region is in Tripura. The lowest productivity of about 4.16 tonnes per ha is observed in Sikkim. Majority of the population is dependent on agriculture, horticulture and allied land based activities. The agricultural production system in the region is mostly rainfed, mono-cropped, and at subsistence level. Productivity of the potato is much less than the national average.

II. Soil characteristic

The extent of variability in soils textural classes vary from sandy loam to clay loam. Old alluvium soils of Brahmaputra valley are sandy loam to clay in texture, while the new alluvial soils are mostly sandy, silty loam or clay loam. The valley soils of Manipur are clay loam to clay in texture. The narrow valley soils of Meghalaya and Tripura contain less amount of clay and richer in organic carbon that their upland counterparts. The texture of the soils in rice fields, orchards and potato fields of Nagaland are loam to clay, the percentage of clay varies from 10 to 31 percent. The soils of entire region are acidic in nature [12]. The pH of old alluvial soils ranges from 4.5 to 5.0, and of the soils close to Brahmaputra ranges from 6.0-7.0, While it varies from 5-6 in the soils of old flood plains. 50% of Sikkim soils were having pH 5 or below, about 45 % between 5 to 6 and the rest 5 % is 6 or above. Acidity in these soils is attributed to the presence of aluminium ($A1^{+++}$) on the clay-complex. Base saturation of soils of Meghalaya and Arunachal Pradesh varied from 30.8 to 84.6 and 23.6 to 80.3 % respectively [13].

III. Indigenous method of potato cultivation:

In the Northeastern India more than two-third of total geographical area is covered by hills. Shifting cultivation (Jhum cultivation) is the common practice in the hills. The practice of shifting cultivation called Jhumming in the hilly areas is generally hazardous and associated with continued degradation of productive soil. It has been estimated that about 2.7 m ha in the hills and forest is exploited for shifting cultivation and as a result vast area of this region has been denudated. The region primarily consists of mountain terrain and different crops including potato are cultivated predominantly on the slopes. Land preparation for potato cultivation is carried out in an indigenous or traditional ways, locally called Nur Bun method. Nur is agricultural land unit in local khasi language and refers to one raised bed, which is usually 1-1.25 m wide and 2-7 m long “Bun” refers to the method of preparation of these raise beds. This age old method of bun system is modified form of Jhum or shifting cultivation, which is commonly referred as the slash and burn method. In this modified form of shifting cultivation, the farmers clears the selected forest areas from all vegetation including trees and use the land for cultivation of some years before they shift to another area of cultivation. Nur Bun method is basically a type of ridge and furrow method, which has been modified to suit the difficult mountain terrain and high rainfall conditions during the potato growing season [14].

3.1 Nur Method:

Farmers perceived that cultivation of potato and others vegetables on raised beds along the slope help them in preventing the washing off the entire crop during heavy rains and storms. The drainage channel laid along with these beds help in drainage away the excess rain water without affecting much the crop on the raised beds. Therefore, farmers hold the strong conviction that preparation of nurs across the slope is operationally not feasible. However, the practice of growing the crop along the slope on raised beds was found to cause heavy soil erosion. According to study carried out in ICAR research complex for north eastern hill region Meghalaya, for every single ton of potato harvested from a field present on 38% hill slope, two tons of soil is lost [15].

3.2 Bun method:

The hilly region of the north east having very high rainfall and humid environment caused robust growth of vegetation. Manually removal of the greases and shrub from the field become cumbersome for preparation of the land of good tillage. Therefore, farmers adopted the Bun method of potato cultivation by burning the dried material along with the soil is perceived to be highly beneficial by the tribal farmers of the state in several ways. It has been repeatedly by them that bun method of land preparation has a positive effect on improving the physical condition of the soil that makes the hard and compact forest soil cultivable. Soil at depth of 20-25 cm, i.e., the height of the raised bed, is made available for cultivation in the traditional Nur Bun method of land preparation, which otherwise would be burdensome to accomplish if forest earth is to be dug and used for planting. The soil in this method becoming light, friable and porous as the ash of the materials burned i.e., twinges, shrubs, leaves, grasses, etc., is added to soil. Farmers also perceived that soil burning in the bun method also helps to improve the soil fertility leading to yield advantages with minimum use of external inputs like chemical fertilizers. Soil burning also minimized the insect pest infestation of the crop. Increased in the availability of nutrients to the plants and thus subsequent increased in the fertility status of the soil. The incidence of disease is also perceived to be low in bun method of land reparation thus resulting in better production. Cutting and burning of plants destroy the well-laid habitats, food supply and the specific environment of insects and pests, thus destroying their populations. Also, insects from the nearby areas get attracted to the light (fire) and get killed. Besides, the soil inhabiting pests are destroyed in the process of soil burning.

3.3 Improved method

In plain region of north east, farmers prefer scientific method like ridge and furrow method was adopted for cultivation of potato. These areas have assured irrigation facility for timely irrigation of crops. The productivity of the potato under plain region was higher as compare to indigenous method of potato. The range of spacing from row to row about 50-60 cm while plant to plant varies from 15 -25 preferably about 20cm. (The farmers follow their traditional system of planting on widely spaced raised beds which accommodate three rows of tubers spaced at 30-35 cm apart between both tubers and rows. Under this system, plant population comes to about 60-70 thousand per ha as against 100 thousand plants/ha under ridge and furrow method of planting). The farmers use more in organic fertilizers than organic manure for cultivation of potato. Standard package and practices were followed under the plain region of north east. Severity of disease and pest is lower as compare to hilly terrain. Farmers community of this region more aware to follow scientific method of potato cultivation might be due to the easily availability of inputs. Due to higher use of fertilizers and pesticides in plain zone resulted in environment and water pollution.

IV. Quality of seed

Inadequate availability and distribution of diseases free seed potato of high yielding varieties adapted to agro-climatic conditions of this region is one of the major constraint. Farmers use seed potatoes which are infected with several diseases [16]. The yield range with the use of own seed of local varieties varies from 10.5 to 20.4 t/ha while yield of quality seed of improved varieties like Kufri Jyoti ranged between 22-30 t/ha with a mean yield of gap of 5-6 t/ha indicating that the quality seed of improved variety is the most important single factor in potato productivity in this region.

V. Soil fertility status

Soil nutritional status of different soils is studied in normal and shifting cultivation and detail information is provided in nitrogen, phosphorous and potassium (NPK) availability. Soils of

Arunachal Pradesh, Manipur, Sikkim are high and that of Assam are medium in available nitrogen. The soils of Tripura, Meghalaya and Nagaland are medium to high in available nitrogen. The contents of available nitrogen were found higher in the valley soils than the adjoining uplands and in the soils of high altitudes. Almost entire soils of Meghalaya, Tripura, Manipur, Arunachal Pradesh and 50 percent of the Nagaland, 40 % of Mizoram and 30 % of Sikkim were low in available phosphorus while soils of Assam were low to medium in available P. Available P Contents in the valley soils were found higher than those in adjoining soils. The contents of available K varied from low to high in the soils of NEH region. Jhumed plots contained higher amount of available K than non-Jhumed plots. The soils of Nagaland and Assam exhibited values of water soluble (exchangeable) K than the soils of Meghalaya and Arunachal Pradesh. Water soluble and exchangeable forms were higher in the upland than the corresponding valley soils of Meghalaya. Potassium applying capacity of the soils of Meghalaya is poor. Very little information is available regarding the status of micronutrients in these soils. Low availability of boron and molybdenum in some soils of Assam and Meghalaya was reported. Available contents of zinc, copper and manganese varied from 0.72 to 3.3, 0.6 to 3.0, 2.3 to 162 ppm respectively in the soils of Meghalaya, Available zinc was higher in the lateritic soils of Assam than the alluvial soils. Soils rich in organic carbon contained lower amount of available copper. However, variation in soil fertility status under shifting cultivation was noticed. Slash and burn (Jhum) procedure is practiced in large areas. The land is planted with mixed-crops for two years and then left to regenerate naturally for 3-6 years. Burning increases the soil pH, available K and exchangeable Ca. The change in pH was temporary, as after the depletion of Ca and K from the soil, the original pH was regained. The total inventory of bio-elements increases linearly with prolonged fallow conditions and attained a maximum level in 20 years. The enrichment ratio was the maximum for P and K indicating their fast rate of conservation in the standing biomass.

VI. Nutrient management:

Being a heavy feeder of nutrients, potato requires high amount of nitrogen, phosphorus and potassium. Chemical fertilizers are the main source of nutrients used for potato cropping [17]. Of these three major nutrient (NPK), it is perhaps inevitable that N has received most attention , for widespread use of substantial amount of P and K has ensured that many soils in areas where potato production is important , have accumulated these nutrients to the points where crop has become relatively intensive to their addition as fertilizers. Excess nitrogen may prolong the vegetative phase and thus, interfere with the initiation of tuberization, decreasing yield and dry matter accumulation in the tubers. On the other hand, a low nitrogen application rate may produce premature senescence in the plants due to early translocation of nitrogen from the leaves to the tubers.The farmers in this region use liberal doses of manures and fertilizers but in imbalanced form. They apply sufficient amount of nitrogen but less doses of phosphatic fertilizers around 40-50 kg P_20_5/ha. Because of acidic nature of soil in this region, these are poor in phosphate availability and utilization of phosphate in this region is only around 10-12%. The level of potassium is high in the region and thus it is not a limiting nutrient.

For achieving higher productivity, the use of nitrogenous fertilizers is increasing, which is leading to the increase in cost of production and also the environmental pollution [18]. Potato productivity relies heavily on nitrogen fertilization representing the major cost in cultivation. Furthermore, there is serious concern regarding nitrogen loss in the field, giving rise to soil and water pollution. Incomplete capture and poor conversion of nitrogen fertilizer also causes global warming through emissions of nitrous oxide. It has been estimated that 50–70 % of the nitrogen provided to the soil is lost. Increasing NUE and limiting nitrogen fertilizer use are both important and challenges to preserve the environment and improve a sustainable and productive agriculture. Therefore, improving NUE is essential in order to reduce damage due to nitrate leaching, ecosystem

saturation and water pollution. Potassium plays an important role in the activation of starch synthetase, and also helps in translocation of starch from leaves to tubers [19].

6.1 Integrated nutrient management:

Modern agriculture largely depends on the use of nutrients and chemicals from inorganic sources. Continuous use of high and imbalanced chemical fertilizers in potato cultivation has led to problems of soil degradation. Excessive use of inorganic fertilizers reduces soil organic matter as well as causes nutrient imbalance and also affects the eco- system [20] Integrated nutrient management (INM) is a better approach for supplying nutrition or food to the crop by including organic and inorganic sources of nutrients [21]; [22]. The increase in protein content due to the application of chemical fertilizers (NPK) and vermicompost/ FYM may be attributed to direct supply of nitrogen. Application of chemical fertilizers with supplementary and complementary use of organic manures and bio-inoculants improves physical, chemical and biological properties of soil, fertilizer use efficiency, mitigates short supply of micro-nutrients, stimulates the proliferation of diverse group of microorganisms and plays an important role in the maintenance of soil fertility and also improves the ecological balance of rhizosphere [23]; [24]. [25] concluded that combined use of organic manure and inorganic fertilizers in suitable proportion improved potato productivity. Application of 40% organic manure and 60% inorganic fertilizers to meet N equivalent of recommended dose of NPK for potato was most effective. The combined use of organic manure and inorganic fertilizers helps to maintain soil health and sustain productivity especially in heavy feeder crop like potato. Higher levels of productivity in potato production were obtained through integrated nutrients use which also maintains the soil fertility status over the years [26].

6.2 Use of Biofertilizers

Bio-fertilizers have shown a good promise and have emerged as an important component of integrated plant nutrients supply (IPNS). Field studies conducted in north eastern hills at Shillong on role of *Azotobacter*, phosphorus solubilizing bacteria and plant growth promoting bacteria on N and P economy revealed that their use improved number of medium and large sized tubers, total tuber yield, economics and also nutrients uptake by potato [27]. Microorganism's inoculations have shown a good promise and have emerged as an important component of integrated plant nutrients supply [28]. Earlier studies also reported an improvement in biological yield of potato with the application of vermicompost and biofertilzers [29]. They are cheaper as well as pollution free and are based on renewable energy source. Besides, they also improve soil physico-chemical properties and soil health in the long run ([30]. The extent of benefit from these micro-organisms depends on their population and efficiency which, in turn is governed by a number of soil and environmental factors. Beneficial effect in the north eastern hill region on yield and growth parameters (plant height, number of leaves and stems/plant) as a result of biofertilizer inoculation has also been reported earlier by [31]; [32] and [33]. In the north western hills, increase in growth parameters by Azotobacter in combination with organic sources of plant nutrients has been reported by [34]. Earlier studies at Shimla also found increased uptake and recovery of P in the presence of PSB [35]. This may be due to beneficial effect of PSB in the acidic soils by the release of native P present in the soil which in turn makes sufficient P in soil solution around root zone [36]. [37] concluded that combined application of 50% recommended dose of NPK through fertilizers along with tuber inoculation with microorganisms and 5 t/ha FYM proved to be more effective in terms of growth attributes, tuber yield, nutrients uptake and recoveries. Radish yield also showed similar trend with respect to different treatments and highest value was recorded under 50% recommended dose of NPK through fertilizers along with tuber inoculation with microorganisms and 5 t/ha FYM.

VII. Potato based cropping systems

To sustain agriculture, efficient cropping system can contribute to a great extent [38]. An effective crop rotation not only helps to increase the crop productivity and soil fertility, but also improves the water use efficiency by reducing weeds, providing conducive microclimate for plant growth and development, reduction in soil thermal regime and improving physical properties of the soil [39]. Highest tuber yield (27.8 t/ha) was recorded with fallow–potato sequence which was followed by green gram–potato sequence. This might be due to fallowing and green manuring which improve soil fertility [40] and [41]. Two crops of potato in summer and autumn seasons are grown in Meghalaya. Several profitable sequential and intercropping systems have been developed in the region. The most popular cropping systems are potato-potato, rice-potato and maize-potato. Several rainfed cropping systems for Meghalaya hills *viz.*,potato (summer)-radish, potato (summer)-potato (autumn), potato (summer) cabbage/cauliflower/beans have been developed and practiced by the farmers. In a field study at Shillong recommended doses of fertilizers to potato as well as to succeeding vegetable crops like cabbage and radish are essential to obtain higher yield and net returns and sustain soil health [42]. Potato-radish (*Raphanus sativus* L.) cropping system gave the highest productivity as well as net return over potato-cabbage [*Brassica oteracea* L. convar.*botrytis* (L) Alef. var. *botrytis* L.] cropping system [43]. But as per the principal of crop rotation potato cabbage was more suitable for sustainable production. Radish and potato both is the highly exhaustive crop for same depth of nutrient as a result of fertility of soil is depleted and system will be become less productive after some time.

VIII. Organic potato production

The Key characteristics include protecting the long-term fertility of soils by maintaining organic matter levels, fostering soil biological activity, careful mechanical intervention, nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, effective recycling of organic materials including crop residues and livestock wastes and weed, diseases and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties [44]. A great emphasis is placed to maintain the soil fertility by returning all the wastes to it chiefly through compost to minimize the gap between NPK addition and removal from the soil [45]. These organic sources besides supplying N, P, and K also make unavailable sources of elemental nitrogen, bound phosphates, micro nutrients and decomposed plant residues into available form in order to facilitate the plants to absorb the nutrients. It encouraged the growth and activity of mycorhizae and other beneficial organisms in the soil and is also helpful in alleviating the increasing incidence or deficiency of secondary and micronutrients and is capable of sustaining high crop productivity and soil health. Over the last few decades, demand for healthier food and government policies on environmentally sustainable agricultural systems have promoted a rapid expansion of organic farming [46]. Potato represents a major food crop in many countries where the demand for organic products is gradually increasing [47]. According to [48] a potential advantage of organic agriculture in producing healthy foods is based on higher concentrations of beneficial secondary plant substances in organically grown crops compared to inorganically grown crops.

A survey based study was conducted by central potato research station, Shillong. During the year 2001-2002 to document the existing potato cultivation practices followed by the tribal farmers. Finding of the studies revealed that tribal potato farmers of Meghalaya were following the combination of traditional as well as improved method of production [49]. In North Eastern region majority of the area lies in the hills, the soils are rich in organic matter and there is also availability of organic manures. The consumption of chemicals fertilizers in the State is very low being only 18 kg/ha as compared to the national average of above 94kg/ha. The total consumption of fertilizers in the state is concentrated mainly in potato and vegetables and to some extent paddy crop in mid and

low altitude areas. There are still villages in the state where chemical fertilizers are still unknown and that crops are being grown organically with organic manures as the only source of plant nutrient.

IX. Weed management

Because of heavy rains, weeds pose a serious problem in potato crop in this region. They compete with the crop for nutrients, moisture, light and space during crop growth period and also act as alternate hosts of insect pests and diseases. They can be controlled by cultural and mechanical methods. Use of herbicides check early weed growth, reduces mechanical damage to the plants and is quick and less laborious. It also minimizes the spread of mechanically transmitted viral diseases like virus X and S by omitting manual weed control during crop growth period. Potato though possesses robust growing and quick spreading habit, yet it poorly competes with weeds because of its extremely slow growth in the initial emergence phase [50].

The proportion of infestation by narrow leaf weed population is more in potato crop compare to broad leaf weed. Therefore, major emphasis to be taken to combat annual narrow leaves weed which can be easily managed by application of several herbicides. However annual broad leaves weed are not a major problem during main season [51]. Critical period of crop weed competition is the prime factor, which decides the growth and yield of potato. The productivity of potato was reported to be reduced considerably when weed competition occurs during the early stages of crop growth. Weeds cause much damage to the potato crop during the first 45 days of its growth. The most critical period of weed competition is from three to six weeks after planting. Chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production cultivation and in this review; various physical, chemical and mechanical methods that curtail the growth and spread of weeds have been discussed. The common weed management practice for potato is pre-emergence application of selective herbicides like metribuzin, oxyfluorfen, Linuron or pendimethalin [52].

X. Diseases and pests

Among diseases, late blight of potato is the most devastating in the region, appears every year in epidemic form causing heavy loss in tuber yield [53]; [54] and [55]. Besides late blight, early blight, scab and bacterial wilt is also found in some place but damages were not as prominent as compare to late blight. The losses in tuber yield can be prevented either by cultivating disease resistant varieties or by means of giving prophylactic sprays with suitable fungicides. The insect pests are not of serious concern in the region except aphids and jassids which cause damage to seed crop, especially in dry years by transmitting viruses and mycoplasma like diseases, which can be managed by using systemic insecticides either by soil application in granular form or by foliar sprays in proper doses.

X. Conclusion

The main constraints to sustain potato production in north eastern region are the shortage of quality seed of improved varieties and inadequate knowledge of farmers on modern technology of potato production. Use of disease free quality seed potatoes of high yielding varieties with improved crop management and crop protection practices will help in sustaining potato productivity in this region. Availability of critical inputs like quality seed potato, fertilizers and plant protection chemicals are to be ensured for greater adoption of improved potato production technologies.

Bibliography

[1] Paul, Khurana. S. M., and Naik, P. S. 2003. The Potato: An overview. In: The Potato: Production and Utilization in Sub-tropics, eds., S. M. Paul Khurana, J. S. Minas, S. K. Pandy, pp. 1-14. New Delhi: Mehta Publishers.

[2] Singh, J.P., Dua, V.K. and Lal, S.S. 2008 Potato based cropping system in India. *Indian farming*. **58** (9) 27-31.
[3] Burman, R. R., Kumar, M., and Nagaraj, K. M.2007. Organic potato production- practices and extension strategy. In: Advances in Organic Farming Technology in India, eds. G. C. Munda, P. K. Ghosh, A. Das, S. V. Nagchan, and K. M. Bujarbaruah, pp. 271–279. Umiam, India: ICAR Research Complex for NEH Region.
[4] Kumar, S., Singh, P.H., Gupta, P.H., Sah, U. ,and Pandey, S.K. 2006. Integrated development of Horticulture in North Eastern states of India (MM- I), Technical bulletin no 76, Central Potato Research Institute, Shimla, pp. 4.
[5] Thiele, G., Theisen, K., Bonierbale, M. and Walker, T. 2010. Targeting the poor and hungry with potato science. *Potato Journal* **37** (3-4): 75-86.
[6] Scott, G.J. and Suarez, V. 2011. Growth rates for potato in India and their implications for industry. *Potato Journal* **36**(3-4): 121-35.
[7] Scott, G.J. and Suarez, V. 2012. The rise of Asia as the centre of global potato production and some implications for industry. *Potato Journal* 39(3-4): 1-22.
[8] Kushwah, V.S. and Singh, S.P. 2011. Relative performance of low input and high input technology for potato production in India. *Potato Journal* **38**(1): 56-60.
[9] Sah, Uma., Dubey, Shantanu Kumar. and Sharma, J.P. 2011. Potato Marketing in North East Region of India: A Diagnostic Study. *Journal of Community Mobilization and Sustainable Development* Vol. **6**(2), 194-201,
[10] Kumar, Shantanu., Sah, Uma., Deka, C., Baishya, L.K., Pandey, N.K., Singh, P.H. and Pandey, S.K. 2008. Farmer participatory research for design and delivery of situation specific potato production technology in Meghalaya. *Potato Journal* **35** (1-2): 78-84
[11] Gupta, V.K., K.C. Thakur., Kumar, S., Pandey, S.K. and U. Sah. 2004. True Potato Seed- An alternative technology for potato production in North eastern hill region. Technical bulletin, no 64, Central Potato Research Institute, Shimla. Pp. 1
[12] Manoj, Kumar., Baishya, L. K., Ghosh, D. C., Ghosh, M., Gupta, V. K. and Verma, Med Ram 2013. Effects of organic manures, chemical fertilizers and biofertilizers on growth and productivity of rainfed potato in the eastern Himalayas, *Journal of Plant Nutrition*, 36:7, 1065-1082,
[13] Chandy, T.K. 2012. Soils of North-Eastern Hill Region. Agricultural & Environmental Education, Booklet No 371.
[14] Dubey, Shantanu Kumar and Sah Uma 2009; indigenous Nur Bun method of potato cultivation in Meghalaya hills. *Asian Agri-History*, **13** (2): 147-153
[15] Mishra,V.K. and Gupta, S.K. 2001. Meghalaya ki bun pranali. Kheti 53:13-15.
[16] Srivastava, A.K., Gupta, V.K.; Lal, B., Roy, S., Yadav, S.K., Gurjar, M. S., Bag, T.K., Pandey, N.K. and Singh, B.P.2012.Assessment of the level of knowledge and training needs of potato growing tribal farmers of Meghalaya. *International Journal of Agriculture, Environment & Biotechnology*. **5** (4) 483-487.
[17] Narayan, Sumati., Kanth, Raihana. H., Narayan, Raj., Khan, Farooq A., Singh, Parmeet and Rehman Shabir U. 2013. Effect of integrated nutrient management practices on yield of potato. *Potato Journal*, **40** (1): 84-86
[18] Jatav, M.K., Kumar, Manoj., Trehan, S.P., Dua, V.K. and Kumar, Sushil. 2013. Effect of nitrogen and varieties of potato on yield and agronomic n use efficiency in north-western plains of India. *Potato Journal*) **40** (1): 55-59
[19] Shambhavi, S. and Sharma, R.P. 2008b . Influence of vermicompost on quality of potato (*Solanum tuberosum*) in wet temperate zone of Himachal Pradesh. *Indian Journal of Plant Physiology* **13**: 185-190.
[20] Sarkar, A., Sarkar, S. and Zaman, A. 2011. Growth and yield of potato as influenced by combination of organic manures and inorganic fertilizers. *Potato Journal*. 38 (1): 78-80
[21] Arora, S. 2008. Balanced nutrition for sustainable crop production. *Krishi World*: 1-5.
[22] Kumar, M., Baishya, L.K., Ghosh, D.C. and Gupta, V.K. 2011. Yield and quality of potato (*Solanum tuberosum*) tubers as influenced by nutrients sources under rained conditions of Meghalaya. *Indian Journal of Agronomy* **56** (3): 260-66.
[23] Singh, S.N., Singh, B.P. Singh, O.P., Singh, Rajpal and Singh, R.K. 2007. Effect of nitrogen application in conjunction with bio-inoculants on the growth, yield and quality of potato under indo-gangetic plain region. *Potato Journal* **34** (1-2): 103-104.
[24] Sarkar, B., Mandal, S.S., Nayek, S.S., Saha, M. and Biswas, S. 2007. Integrated nutrient management for the productivity and quality improvement of potato under irrigated condition. *Potato Journal* **34**(1-2): 99-100
[25] Patel, C.K., Sasani, G.V. Kadian, M.S. Patel, R.N. and Patel, N.H. 2002. Integrated nutrient management in Potato (Solanum tuberosum). Paper presented in 2nd International Agronomy Congress, Nov. 26-30, New Delhi, India.
[26] Roy, S.K., Sharma, R.C. and Trehan, S.P. 2001. Integrated nutrient management by using FYM and fertilizer in potato-sunflower-rice rotation in Punjab. *Journal of Agricultural Sciences* **137**: 271-78.
[27] Singh, K. 2000. Effect of inoculation with Azotobacter and Phosphobacteria on potato (*Solanum tuberosum*) in north- eastern hills. *Indian Journal of Agricultural Sciences* 70(6): 385-386.
[28] Kumar, V., Jaiswal, R.C. and Singh, A.P. 2001. Effect of biofertilizers on growth and yield of potato.
[29] Mohapatra, B.K., Maiti, S. and Satapathy, M.R. 2008. Integrated nutrient management in potato (*solanum tubnerosum*)-Jute (*Corchorus olitorius*) sequence. *Indian Journal Agronomy* **53** (3): 205-09

[30] Singh, K. 2001. Response of potato (Solanum tuberosum) to bio- fertilizer and nitrogen under north-eastern hill conditions. *Indian Journal of Agronomy* **46** (2): 375-379.
[31] Singh, K. 2002. Role of biofertilizers in increasing the efficiency of nitrogen to potato crop under north eastern hill conditions. In: Potato, Global Research and Development Vol. 2 (SM Paul Khurana et al., Eds). Indian Potato Association, CPRI, himla pp. 904-07.
[32] Singh, S.K. 2002a. Effect of phosphobacteria, nitrogen and phosphorus on the tuber yield of potato (Solanum tuberosum) under East Khasi hill conditions of Meghalaya. *Indian Journal of Agronomy* 47(2): 273-277.
[33] Singh, S.K. 2002b. Efficacy of phosphate solubilizing biofertilizer with phosphorus on potato yield.In: Potato, Global Research and Development Vol. 2 (SM Paul Khurana et al., Eds). Indian Potato Association, Central Potato Research Institute, Shimla pp. 908-11.
[34] Sood, M.C. and Sharma, R.C. 2001. Value of growth promoting bacteria, vermicompost and *Azotobacter* on potato production in Shimla hills. J. Indian Potato Assoc. 28(1): 52-53.
[35] Sud, K.C. and Jatav, M.K. 2007. Response of potato to phosphorus and phosphorus solubilizing bacteria in brown hill soils of Shimla. *Potato Journal* **34**:109-11.
[36] Anonymous.2008. Annual Scientific Report, Central Potato Research Institute, Shimla, pp. 144.
[37] Jatav, M.K., Kumar, Manoj., Trehan, S.P., Dua, V.K., Lal, S.S. and Sharma,R.P.2012. Influence of microorganisms inoculation on nutrient economy in Potato- radish crop sequence in North Western Himalayas. *Vegetable Science* 39 (1): 21-25.
[38] Faroda, A.S., Joshi, N.L., Singh, R. and Sexena, A. 2007 Resources management of sustainable crop production in arid zone – A review. Indian Journal of Agronomy **52**: 181-93.
[39] Singh, S.P., Kushwah, V.S. and Lal, S.S. 2011. Integrated nutrient management in blackgram–potato–wheat sequence Potato Journal **38** (2): 170-75
[40] Singh, S.P. and Lal, S.S. 2013. Evaluation of different cropping systems for their productivity and sustainability in Madhya Pradesh. Potato Journal **40** (2): 149-154.
[41] Yadav, R.L., Yadav, D.V. and Majumdar, D. 2008. Rhizospheric environment and crop productivity-a review. *Indian Journal Agronomy* 53: 1-17.
[42] Singh, S.K. and Lal, S.S. 2002. Integrated nutrient management in potato-vegetables crop sequence under rainfed hilly condition of Meghalaya. *Journal of the Indian Potato Association* **29** (3-4): 147-151.
[43] Singh, J.P., Dua, V.K., Kumar, Manoj., Govindakrishnan, P.M. and Lal, S.S. (2008). Cultural management of crops in potato based cropping systems in India, CPRI, Extension Bulletine No. 39, Central Potato Research Institute, Himachal Pradesh, India, 48 pp.
[44] Yadav, S. K., Babu, Subhash., Yadav, M. K., Singh, Kalyan., Yadav, G.S. and Pal, Suresh. 2013. A Review of organic farming for sustainable agriculture in northern India. *International Journal of Agronomy*, vol. 2013, 1-8 pages, doi:10.1155/2013/718145.
[45] Chhonkar, P.K. 2002. Organic farming myth and reality. FAI Seminar on Fertilizer and Agriculture Meeting the Challenges, New Delhi, 16-18 Dec., 2002.
[46] Jaipaul., Sharma, Sanjeev. and Sharma, Ashok K. 2011. Effect of organic fertilizers on growth, yield and quality of potato under rainfed conditions of central Himalayan region of Uttarakhand. *Potato Journal* **38** (2): 176-181.
[47] Maggio, A., Carillo, P., Bulmetti, G.S., Fuggi, A., Barbieri, G. and Pascale, S.D. 2008. Potato yield and metabolic profiling under conventional and organic farming. *European Journal of Agronomy* **28**: 343–350.
[48] Köpke, U. 2005. Organic Foods: Do They Have a Role in Diet Diversification and Health Promotion. Forum Nutr. (Elmadfa, I.,Ed.), Basel, Karger AG **57**: 62–72.
[49] Anonymous.2002. National Horticulture Board, Year Book–2002, Associated Publishing Company, New Delhi, pp. 230.
[50] Channappagoudar, B. B., Biradar, N R., Bharmagoudar, T. D. and Koti R.V. 2007. Crop weeds competition and chemical control of weeds in potato. Karnataka Journal of Agricultural Science. **20** (4):715-718
[51] Yadav, S.K., Srivastava, A.K., Gurjar, M. S. and Bag, T. K. 2013. Major weeds of potato and their management in Meghalaya hills. *Agrobios Newsletter* **10**: 45-46
[52] Yadav, S.K., Lal, S.S., Srivastava, A.K., Bag, T.K., 2014. A review on weed management in potato (*Solanum tuberosum*) in north eastern hill region of India. *International Journal of Agriculture*. Photon 125, 279-284.
[53] Struik, P.C., 2009. Can physiology help us to combat late blight in potato? Potato Research **53**, 277–287.
[54] Lammerts, Van Bueren, E.T., Tiemens-Hulscher, M., Struik, P.C., 2008. Cisgenesis does not solve the late blight problem of organic potato production: alternative breeding strategies. *Potato Research* **51**, 89–99.
[55] Finckh, M.R., Schulte-Geldermann, E., Bruns, C., 2006. Challenges to organic potato farming: disease and nutrient management. *Potato Research* 49, 27–42.

