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Abstract: The main objective of this review was to overview the role of integrated nutrient management for coriander (Coriandrum sativum L.) crop production with putting direction on how to increase production and productivity by considering factors such as soil, climate and varieties particularly in Ethiopia. Nutrient application from all sources such as organic, inorganic and biofertilizers are very important for increasing crop production. Like other crops, coriander also requires nutrients for growth and development. The soil needs continuous input as nutrients are exported or leached out from the soil. Integrated soil nutrient management is critical to increase productivity and efficient use of available nutrients. Management of soil fertility status using the right fertilizer at the right rate is a basic approach for nutrient management and can be applied to coriander production as well. The integrated nutrient management which combines the use of organics; manures, composts, biofertilizers and inorganic fertilizers increases product yields, improve quality and minimize nutrient losses to the environment. The combinations of those nutrients together with optimum ratio are a way forward to achieve reasonable yield and increasing the quality of coriander. Therefore, integrated nutrient application of organic, biofertilizers and inorganic fertilizers is the best option to increase the yield potential, benefit cost ratio and quality attributes of coriander

Keywords: Coriander, integrated nutrient management, fertilizers, variety, growth and yield, climate and soil.

1. INTRODUCTION

Coriander is a member of the parsley (Apiaceae) family (Sharma et al., 2012; Khan, 2019). It is native to the Mediterranean and Middle East, and found wild in Egypt, Ethiopia and Sudan. The cultivation of coriander has been since antiquity and was one of the first spices used by mankind.
Coriander is an annual plant which has slender green stems that can grow up to 40-60 cm and the leaves resemble parsley leaves (Mahr, 2017). The lower leaves are compounded, while the upper leaves are finely divided into very narrow segments (Blade et al., 2016). It produces white flowers and light brown seeds. The seeds are round and tannish brown. They are available in most markets as spice (Diederichsen, 1996; Mahr, 2017).

Coriander can refer to both herb and spice. Herbs are the fresh, leafy part of a plant (JSS, 2018). Spices come from the seeds, root or bark of the plant and are considered any edible part of the plant, besides the leaf, that can be used for seasoning; some plants have both. Therefore, most of the time cilantro refers to the leaves while coriander is to indicate the seeds.

Coriander is used in cooking, as an ingredient in preparation of different food dishes, and can be distilled into essential oils (Filippone, 2018; JSS, 2018). Cilantro leaves and coriander seeds taste very different and cannot be substituted for each other in recipes (Filippone, 2018). The leaves have different taste as compared to its seeds (Bhat et al., 2014). Coriandrum sativum is one of the most useful essential oil bearing spices as well as medicinal plants (Mandal and Mandal, 2015). Coriander seeds contain high amount of minerals which are very important to regulate body’s metabolism and widely used in folk medicine in addition to its use as a seasoning in food preparation (Sharma et al., 2012; Mandal and Mandal, 2015). It is an essential component of ayurvedic medicine used for treatment of digestion and gastric ailments. Essential oils of its seed extracts possess numerous valuable constituents which could be exploited for the preparation of medicinal combatants against several acute and chronic diseases (Sharma et al., 2012; Khan, 2019). It is very low in saturated fat however, contains good amount of linoleic acid which is a good source of α-tocopherol and vitamin K (Bhat et al., 2014).

Ethiopia has a long history in using spices as food ingredients and medicinal purposes. In addition, Ethiopia is considered as the homeland for many spices such as korarima, long pepper, black cumin, bishops weed and coriander (Hilde and Daphne, 2003). Some literatures also pertaining that coriander apparently had Ethiopian origins; other key spices arrived much later, when Ethiopia began to have contact with Europe (Kloman, 2014).

Production of coriander continues to be constrained by a number of factors that can reduce yield quantity and quality like other crops (Wang et al., 2013). Among those factors, fertilizer management has considerable practical importance. Fertility status of the soil can be reduced due to leaching, exporting, mineralization, immobilization or other means. Therefore, extensive fertilizer applications are required to meet the crop demand of nutrients to obtain good return (Reetz, 2016). However, continuous application of suboptimal doses of fertilizers may leads to depletion of nutrient reserves in the soil. To meet the crop nutrient requirements, it’s essential to apply nutrients from different sources in modern cropping system (Mahajan and Gupta, 2009). It’s stated that integrated use of chemical fertilizers with organic manures and biofertilizers were found to be the most promising to maintain higher productivity and provide sustainable crop production (Tripathi et al., 2013; Biramo, 2018).

Despite Ethiopia has a diverse favorable agro-ecologies, germplasm availability and released opportunities; research attention given to coriander crop is very low (Awas et al., 2016). The overall productivity of coriander is low due to lack of fertilizer management (Habtewold et al, 2017). Due to the continuous decrease in nutrient content of the soil, integrated nutrient management is very important for efficient use of nutrient resources and for long-term maintenance of soil fertility (Biramo, 2018). Therefore, the plant nutrients from all sources are needed for higher crop production (Reetz, 2016).

In considering the above points, this literature presents a brief review about the role of integrated nutrient management in coriander production with direction for how to use in a sustainable manner.

2. OVERVIEW OF ETHIOPIAN CORIANDER

Coriander has been cultivated so far and contains a long history in Ethiopia. The native names for coriander indicated that it has a long tradition of cultivation. For example; in Amharic it’s called...
(Dembilal), in Afan Oromio (Debo or Shukar), in Tigigna (Tsagha or Zagda) and in Konso (Tibichota) (Habtewold et al., 2017). In addition, most Ethiopian people use coriander as house holding spice preparation. The powder of pepper which is very important in vegetarian dishes is prepared by using coriander as ingredients. Coriander helps with flatulence and cramps, relieves indigestion, and can serve as an aphrodisiac (Diederichsen, 1996; Zuberi et al., 2014). It is also one of the ingredients in bread preparation and in treating serious coughing (Tesfa et al., 2017).

Coriander can be found in almost every market in Ethiopia. This is because of small-scale cultivation in gardens is widespread. The Ethiopian types have well-developed rosettes from four to nine basal leaves of characteristic shape. The heterophyll is only slightly expressed, and the plants have many leaves and are much branched (Diederichsen, 1996). The aroma of Ethiopian coriander is somewhat felt between cumin and cardamom (Kloman, 2014). Harvesting is done from November to January (ITC, 2010). Appearance of red pod is an indication of maturity to harvest. Harvesting is practiced by uprooting the plant and sun dried and then threshed (ITC, 2010; Tesfa et al., 2017).

2.1 Climate and Soil Requirements

The most spices grown and traded throughout the worlds are the products of tropical region. But, coriander can grow over a much wider range of tropical and non-tropical environments (UNIDO & FAO, 2005; Awas et al., 2016). Cilantro/coriander is a cool-season herb that grows best in full sun and fertile, well-drained soils (Miller and Drost, 2018). The crop is well suited to growing on a range of soils (Miller and Drost, 2018; Habtewold et al., 2017), but it performs best on well-drained loam and sandy-loam soils. The soil pH requirement of coriander ranges 4.5 to 8.0 with an optimum of 6.3. Although the crop is heat loving, it has an optimum growing temperature of 18°C (Blade et al., 2016).

In Ethiopia, coriander is an important cash crop for farmers in the relatively highland areas. It is often cultivated in altitude ranges from 1200 to 2200 m.a.sl. It also requires 120 to 400 mm rainfall per growing period. Coriander can be cultivated successfully under a wide range of climatic and soil conditions (Diederichsen, 1996; Awas et al., 2016). However, frost-prone areas must be avoided particularly during flowering and seed formation stages. Relatively cool weather during early stage favors better vegetative growth, while relatively high temperature favors both yield as well as quality of seed. For green leaves purpose, it can be grown throughout the year provided moisture is made available (Blade et al., 2016). It is usually grown as a rain-fed crop, although it can be grown with irrigation where required (Miller and Drost, 2018). Coriander can be cultivated on almost all type of soils provided sufficient organic matter is available. Rich loam soil is best suited and heavy soils having better water retention capacity and vertisols are also suited under rain fed conditions (Habtewold et al., 2017).

2.2 Variety

Ethiopia is a center of primary diversity for coriander (Coriandrum sativum L.). However, the current knowledge about its biology, variety development and agronomy are neither complete nor conclusive under Ethiopian conditions (Mengesha et al., 2018). The research attempt made so far on spices as a whole is relatively very limited and recent phenomena in Ethiopia. Only a few production technologies have been developed and a few improved varieties released for limited areas. However, production technologies developed were limited because of not yet multiplied and popularized to farmers. As a result, the overall productivity and quality is low and the production systems so backward (Habtewold et al., 2017). According to the study conducted to test trial on 49 coriander accessions, there existed variability among accessions. The study brought out the presence of substantial genetic variability for the important traits among genotypes suggesting clue to improve the productivity of the crop through selection and breeding that enhance its cultivation (Mengesha et al., 2018). Studies have also indicated that there is wide range of genetic diversity for coriander improvement in Ethiopia. Accordingly, hybridization among accessions from different clusters of 81 coriander genotypes identified in the study could lead to considerable genetic improvement by following appropriate selection strategies in the segregating generations (Awas et al., 2016). The only three released varieties are; Indium 01, Walta-I and Denkinesh (Table 1).
2.3 Coriander Production Status

Ethiopia has around 18 major agro-ecological zones and various agro-ecological subzones. There are suitable climates for growing more than 146 types of crops and have been producing a number of spices. Among 109 spices shortlisted by International Organizations for the Standardization (ISO), the country produces not less than 50. Out of 50 most produced spices and herbs, 23 are trading as export items. Ethiopia mainly produces ginger, turmeric, cumin, rosemary, cardamom, capsicum, fenugreek, coriander, korarima, black pepper, hot pepper, rue, celery and thyme (EIC, 2019). For example, the markets in Dire Dawa and Harar were found to sell more of fenugreek and coriander, whereas the Jimma-Aggaro markets are specialized in selling cardamom, korarima, ginger and garlic. On the other hand, in Hosaina market; fenugreek, caraway, garlic, and coriander were more common (Fullas, 2009).

Coriander production has a long history in Ethiopian agriculture as it was produced locally in the garden as common spices (Kloman, 2014). The productivity of coriander varies depending on the agro-ecology under which it’s grown and the type of variety. It ranks second among the seed spices produced in Ethiopia in terms of area coverage next to fenugreek and the third in terms of yield next to black cumin. As stated in the 2007 annual report of the Ethiopian Ministry of Agriculture and Natural Resource, about 21645 ha of land are covered by coriander with its annual production estimated to be around 1535 tons. The national average productivity is 0.25 ton ha⁻¹. However, yields of 1.0 to 2.4 ton ha⁻¹ have been found from the two released varieties of “Indium 1” and “Walta-I” (Habtewold et al., 2017).

According to Ethiopian spice sub-sector, exports in 2009/10 of coriander were at the same level as in 2008/09 (ITC, 2010). But, according to Yimer (2010), the volume of coriander export is at decreasing rate from the year 2005 to 2010. The crop is mainly exported to Singapore and Yemen which is followed by UAE and Djibouti (Yimer, 2010). However, according to FAO (2019) report, area harvested and production of coriander together with other spices in Ethiopia is at increasing rate.

![Figure 1: Total area coverage and production of coriander together with other spices (Anise, Badian and Fennel) in Ethiopia. Source: FAO (2018).](image-url)
3. NUTRIENT REQUIREMENTS OF CORIANDER

Crop nutrient management is important phenomena in agricultural crop to provide ample nutrient demand for crop growth and development throughout the growing period. If the amount of any nutrient is limiting, there is a potential for yield loss in production (Reetz, 2016; Basak et al., 2017). By several means nutrients are exported from the fields where crops are grown and nutrient supply in the soil can become depleted. Thus, supplementing is required through application of external fertilizers. Furthermore, the farmer’s economic returns have increased substantially due to fertilizer use in crop production (Reetz, 2016).

Improved varieties of highland seed spices such as coriander, black cumin and fenugreek were proved to be performing very well in highlands of Ethiopia with enough soil nutrient management (Hailemichael et al., 2016). Cilantro requires good soil fertility; otherwise, the production and productivity is reduced. In addition, the crop responded to fertilizer limitation; the leaves become pale yellow. However, soil that is too rich can also cause a diluted flavor (JSS, 2018). As a solution, the current area of investigation in crop production; integrated nutrient management encompasses varied concepts and applications. It involves three basic components; microbial inoculants (bio-fertilizers), inorganic and organic fertilizers (Srivastava and Ngullie, 2009).

3.1 Organic Fertilizers Requirements

Basically, organic fertilizers are a by-product of biological materials. These fertilizers take longer time to release nutrient in the soil. Because they take long time for decomposition, plants may face lack of nutrients if not applied timely. Literature stated that organic fertilizer can influence different attributes of coriander crop. It can influence production through adding nitrogen to the soil (legumes), nitrogen conservation (by reducing leaching) and making nitrogen available to plant (Rayns and Rosenfeld, 2010). But, intensive use of organic fertilizers alone can affect physico-chemical properties of the soil which results in decreased soil fertility status (Chauhan et al., 2012). Organic fertilizer including farmyard manure, poultry manure and compost are used for several decades ago in the history of different agricultural crops. These fertilizers are environmentally eco-friendly when compared to inorganic fertilizers (Chauhan et al., 2012; Ahmad et al., 2017).

The study have shown that the highest number of leaves branch⁻¹ (6.24), highest leaf area (14.95 cm²) and minimum days taken to harvest (40.75) was recorded from plants received poultry manure in comparison to farmyard manure and compost. Accordingly, compost led to late germination (14.33) of coriander crop, while early germination (11.66) occurred in poultry manure (Ahmad et al., 2017). The quick germination in poultry manure is due to enriched nitrogen content as compared to farmyard manure and compost. Also some organic manure possesses organic acid that help in quick germination of the seed. But, total soluble solids (B⁰) and chlorophyll content (mg cm⁻²) do not significantly affected by the application of organic fertilizers (Ahmad et al., 2017).

Utilization of vermicompost is the most excellent means of reducing environmental pollution, soil degradation and removal in discriminate use of chemical fertilizers. It’s reported that vermicompost is rich in nutrients like O, C, N, P, K, Ca, Mg, Fe, Zn, Cu, Mn and Br when compared to farmyard manure. The higher germination percentage (94%), root length (8.4cm), shoot length (24.8cm), plant fresh weight (16.7 g), plant dry weight (7.8g), total chlorophyll (6.8 mg.fr.wt) and protein (23.32 mg.fr.wt) was recorded in vermicompost application at 90 days after sowing of coriander plant. The minimum recorded in control at 90 days after sowing of coriander plants (Ravimycin, 2016). But, vermicompost is found to be more useful when supplied with inorganic fertilizers. Accordingly, the study reported that the solely application of vermicompost and inorganic fertilizers did not influence coriander crop rather integrated application of vermicompost (7.5 t ha⁻¹) with 25% recommended NPK (25: 12.5: 12.5 kg ha⁻¹) produced maximum biomass (28.2 q ha⁻¹), seed (10.82 q ha⁻¹) and oil yield (6.53 kg ha⁻¹) of coriander (Singh, 2011).

Vermicompost also increases growth rate because of water and mineral uptake by plants such as; nitrogen and phosphorus. Fresh weight of coriander plant increases because of vermicompost application. In relation to this, the study has shown that the highest fresh weight of plant (85.4 g), dry weight of plant (79.6 g), and biomass yields (19924 kg ha⁻¹), were obtained with applying 9 ton ha⁻¹ of vermicompost. However, combined application of vermicompost (9 ton ha⁻¹) and biostimulant (azotobacter and azospirillum) inoculated seed was helpful in the development and production of...
coriander as interaction of vermicompost and biostimulant increased dry weight of the plant to (83.7 g) (Darzi et al., 2014).

In general, agro-environmental problems are not limited to the use of chemical fertilizers only but also occur with organic fertilizers. Both organic and chemical fertilizers have the potential of environmental pollution. Organic fertilizers contain nitrogen rich materials, high extractable nutrients (P, K, Ca, Mg, Cu, Zn,) and can significantly raise soil fertility in the medium to long term. Thus, continued application of organic fertilizers will increase levels of soil nutrients, could cause a buildup of some nutrients, and loss of nutrients to the environment. In addition, decomposition of organic material is strongly affected by temperature and soil moisture thus nutrients may be released when plant does not need them. Only a limited amount of organic material is available and it is generally difficult to meet crop nutrient demands through organic fertilizers alone. This implies that crops can suffer initial starvation from nutrient immobilization prior to mineralization (Sharma and Chetani, 2017). Therefore, the best option is to apply nutrients from different sources; organic, inorganic and biofertilizers (Chauhan et al., 2012).

3.2 Bio-fertilizers Requirements

The use of bio-fertilizers increases the soil potency. These are low cost and safety for the environment, therefore make bio-fertilizers advantageous as an alternative to mineral fertilizers. Application of biofertilizers provides effective implementation of biological mechanism of plant nutrition, growth promotion and protection (Hnamte et al., 2013). Biofertilizers have also emerged as an important component of integrated nutrient supply system and have shown promise to improve crop yields and nutrient supplies. Azotobacter, potassium solubilizing bacteria and azospirillum are the most widespread biofertilizers significantly contributing nitrogen, phosphorus and potassium to plants and also providing resistance to drought situation. However, information regarding the use of biofertilizers is very limited (Mounika et al., 2018).

The plant treated with biofertilizers become physiologically more active and enables to synthesize required amount of hormones or to build up adequate food reserves. Accordingly, the use of bio-fertilizers significantly promoted early flowering, fruit setting and seed maturity as compared to uninoculated plants (along with NPK, vermicompost and cow dung manures) in coriander production. With combined inoculation of biofertilizers consisting of Azospirillum, Azotobacter, PSB and KM along with vermicompost and NPK, have greater influence on early 50% flowering (61.66 days), 50% fruit setting (79.49 days), seed setting (96.79 days), complete maturity (103.96 days), and the highest seed yield (13.34 q ha⁻¹) (Hnamte et al., 2013).

The Study have also found that biofertilizers application recorded the highest plant height at harvest (70.78 cm), number of primary branches at harvest (6.72), secondary branches per plant (15.51) and lowest days to maturity (96.75) (Mounika et al., 2018). Coriander yield can be increased by the application of bio-fertilizer. But, the most significant plant height (55.23 cm), umbel number per plant (74.25), weight of 1000 seeds (8.50 g), dry weight of plant (17.83 g), seed yield (2378 kg/ha), was obtained from treatment with combination of recommended dose of 100% K and 75% NP along with Azotobacter, Azospirillum and PSB. Therefore, biofertilizers are more beneficial when applied with other organic and inorganic fertilizers (Sahu et al., 2013).

3.3 Inorganic Fertilizers Requirements

Maintaining and keeping soil health has paramount importance for sustainability of ecosystem. The effect of long-term application of inorganic fertilizers on soil biological properties is of topical importance for up keeping soil health. Nitrogen supplying fertilizers upon hydrolysis also produce ammonium, decrease soil pH and affecting activities of those microbes (Basak et al., 2017). Farming can be more profitable with higher crop yield through use of those inorganic NPK fertilizers. But, wide disparities in NPK ratio along with inability of integrated use of all sources of plant nutrients deteriorate soil health and thus nutrition of plants (Reetz, 2016).

Micronutrients applications have influenced growth, yield attribute and yield of coriander significantly. For instance, soil application of copper (11 kg ha⁻¹) with foliar application of iron (0.5 % W/V) resulted in early germination i.e. in 10.22 and 10.11 days after sowing, respectively. Maximum
yield was recorded 1651.54 kg ha\(^{-1}\) and 1633.62 kg ha\(^{-1}\) in the above said treatments, respectively (NRCSP, 2013).

Nitrogen and phosphorus are the two major nutrient required for good production or yield of coriander. Increasing seed yield of coriander ultimately depends on good yield contributing characters, which results from proper dose of fertilizers. To standardize the rate of two major nutrients nitrogen and phosphorus, studies have shown that, significantly maximum number of umbels plant\(^{-1}\) (17.93), umbellate umbel\(^{-1}\) (6.69), seeds umbel\(^{-1}\) (18.34), seed yield plant\(^{-1}\) (4.01 g), seed yield plot\(^{-1}\) (341g) and seed yield ha\(^{-1}\) (12.36 q) were recorded with treatment N (60kg ha\(^{-1}\)) and P (50 kg ha\(^{-1}\)) instead of highest dose of both nutrients. But, umbellate per umbel and seeds per umbel interaction effect was found to be non-significant (Pooja \textit{et al.}, 2017). Accordingly, the experiment results revealed that application of 60 kg N ha\(^{-1}\) promoted seed yield (1483 kg ha\(^{-1}\)) and stover yield (1760 kg ha\(^{-1}\)) with higher net return (65976 ha\(^{-1}\)) and benefit cost ratio (3.48) over untreated (Javiya \textit{et al.}, 2017). Conversely, frequent application of nitrogen fertilizers is likely to increase the concentration of nitrate in ground water which is detrimental to human health (Elasbah \textit{et al.}, 2019).

Application of phosphorus enhanced significantly growth and yield attributes. For example, 40 kg P\(_2\)O\(_5\) ha\(^{-1}\) increased seed yield (1388 kg ha\(^{-1}\)) and stover yield (1613 kg ha\(^{-1}\)) of coriander. The yield further increased with increasing level of P\(_2\)O\(_5\) but could not reach up to level of significant. The maximum net realization of (61008 ha\(^{-1}\)) obtained with 60 kg P\(_2\)O\(_5\) ha\(^{-1}\), but benefit cost ratio maximum (3.26) was obtained with 40 kg P\(_2\)O\(_5\) ha\(^{-1}\). It also significantly increased content and uptake of NPK kg ha\(^{-1}\) at 60 kg N ha\(^{-1}\) and 60 kg P\(_2\)O\(_5\) ha\(^{-1}\) in seed and stover (Javiya \textit{et al.}, 2017).

It’s that balanced fertilizer application improved the availability of phosphorous, nitrogen and other nutrients, helped in increasing the yield attributing characters (Mounika \textit{et al.}, 2018). However, the continuous use or excess supply of inorganic fertilizers as source of nutrient in imbalanced proportion is also a problem, causing economic inefficiency, damage to the environment and in certain situations harm plants themselves and also to human being who consume them (Dolker \textit{et al.}, 2017).

4. EFFECTS OF INTEGRATED NUTRIENT MANAGEMENT ON CORIANDER

4.1 The Importance of Integrated Nutrient Management

To meet the entire crop nutrient requirement, different fertilizer types have to be applied in an integrated manner, as applying of single dose of nutrient can’t fulfil the crop nutrient demands (Mahajan and Gupta, 2009).

Intensive inorganic fertilizer usage in agriculture causes so many health problems and unrecoverable environmental pollution. Inorganic fertilizers accumulate salt which expends more energy to draw water from the soil and cause plants to appear wilted or dried out and if there is a rainfall shortly after applied, fertilizers wash away and can pollute streams, ponds and other water bodies. It can also leach away from the root zone of plants. It may enter through plant to the food chain and they get accumulated and harm human health (Sharma and Chetani, 2017).

Organic fertilizers take longer time to release nutrient in the soil. Continued application of organic fertilizers increase levels of soil nutrients, could cause a buildup of some nutrients, and loss of nutrients to the environment (Chauhan \textit{et al.}, 2012; Sharma and Chetani, 2017). Rather, these need to be used in an integrated manner following a management technology which is practicable, economically viable, socially acceptable, and ecologically sound (Mahajan and Gupta, 2009).

The approach involving multiple microbial inoculation (biofertilizers) along with enrichment organic manures or crop residues by loading with inorganic fertilizers is increasingly been shown to modulate nutrient dynamics within the rhizosphere, which is usually termed integrated nutrient management (Srivastava and Ngullie, 2009). Furthermore, as compared to organic, inorganic fertilizers are costly and unaffordable to farmers. The best remedy for soil fertility management is therefore a combination of both inorganic and organic fertilizers, where inorganic fertilizer provides nutrients and organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil.

Several researchers have demonstrated the beneficial effect of integrated nutrient management in mitigating deficiency of many secondary and micronutrients (Biramo, 2018). The study have shown that INM enhances the yield potential of crops over and above achievable yield with recommended fertilizers, and results in better synchrony of crop nitrogen needs due to (a) slower mineralization of
organics, (b) reduce nitrogen losses to environment through denitrification and leaching of nitrate, (c) enhanced nutrient use efficiency and recovery by crops, and (d) improves soil health and increase productivity. Therefore, integrated nutrient application can increase crop yields in various cropping systems and it’s important in ensuring long-term sustainability of the system (Aulakh, 2010).

4.2 Effects on Growth and Yields of Coriander

Cultivation of nutrient responsive crop using eco-friendly innovative techniques like integrated use of organic manures along with inorganic fertilizer for sustainable use of available resources has proved to be best way to increase production level (Nabi et al., 2018). Integrated nutrient management is a crucial and the most efficient in increasing the growth and yield potential of coriander crop (Jhariya and Jain 2017). Accordingly, studies have found that integration of organics with inorganic source of nitrogen (urea) resulted in significant influence on various growth and other parameters as compared to sole application of various levels of nitrogen through urea. Maximum number of lateral branches plant$^{-1}$ (8.50) and minimum days taken for 50% germination (19.63) was recorded by treatment with 50% nitrogen through urea and 50% nitrogen through vermicompost (Nabi et al., 2018).

Similarly, study found that combined application of organic and inorganic manure and fertilizer were improve soil fertility and crop yield of coriander. The use of integrated nutrient such as vermicompost, Nitrogen and phosphorus as organic and inorganic sources was recorded the best yield of coriander. A combined application of vermicompost (2.5 ha$^{-1}$) with N level (40 kg ha$^{-1}$) and P level (20 kg ha$^{-1}$) significantly increased all the yield, quality and uptake parameters; where vermicompost increased seed (10.11 q ha$^{-1}$), stover (16.71 q ha$^{-1}$) and biological yield (26.81 q ha$^{-1}$), oil and protein content, total N, P and K uptake by coriander over the other treatments. And Nitrogen; 40 kg ha$^{-1}$ increased the seed, stover and biological yield by 73.80, 37.98 and 50.89 percent respectively over control. This is due to improved overall growth and profuse branching due to nitrogen fertilization coupled with increased net photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures (Sanwal et al., 2017). In addition, the use of integrated nutrient management of 75% RDF (where 100% RDF is 15-40-20 NPK Kg ha$^{-1}$), Azospirillium and PSB (5g kg$^{-1}$ of seed as seed inoculation with 5 kg ha$^{-1}$ as soil application) recorded maximum number of seeds per umbel (40.40), 1000 seed weight (13.71 g), minimum number of days taken to seed setting (78.43 days), seed harvest (89.46 days), maximum seed yield per plant (5.50g), seed yield per plot (385.00 g) and seed yield per hectare (1283.33 kg) (Suman et al., 2019).

When farmyard manure, recommended dose of fertilizers (100%), and biofertilizers (Azotobacter, Azospirillium, PSB) are combined, it increases mean fresh weight of the leaf ha$^{-1}$, 381.9% more over untreated. Dry plant weight ha$^{-1}$ of 0.79 ton was recorded in farmyard manure, recommended dose of fertilizers (100%), and biofertilizers (Azotobacter, Azospirillium, PSB) treatment and the lowest mean dry plant weight ha$^{-1}$ of 0.35 ton without treatment (Jhankar et al., 2017).

According to the research conducted to find out the effect of integrated nutrient management on growth and yield attributes in radish and its residual effect in coriander in radish cropping sequence, adoption of either FYM (20 t ha$^{-1}$), fertilizer (80:60:80 NPK kg ha$^{-1}$), PP with organic methods, and IIHR microbial consortium (12.5 kg ha$^{-1}$) or FYM (20 t ha$^{-1}$), fertilizer (80:60:80 NPK kg ha$^{-1}$), PP chemicals, and IIHR microbial consortium (12.5 kg ha$^{-1}$), had significant positive influence on vegetative growth such as plant height (15.20-16.39 cm), leaves plant$^{-1}$ (5.83-6.18). However, significantly highest leaf yield was observed in treatment with vermicompost (12.5 t ha$^{-1}$) (PP with organic methods) (4.53-4.60 kg plot$^{-1}$), and FYM (20 t ha$^{-1}$) (PP with organic methods) with IIHR microbial consortium (12.5 kg ha$^{-1}$) (PP with organic methods) (55.93-56.79 q ha$^{-1}$) (Dash et al., 2019). For example, the following table shows the maximum seed yield gained when nutrient is applied in integrated manner as compared to sole application.

Several authors have been agreed up on integrated nutrient application as it is sustainable, ecofriendly and free of contamination. Applying any fertilizer lonely cannot fulfill crop nutrient demand. The highest seed yield of coriander is obtained when different fertilizers are combined together. Applying of inorganic fertilizers lonely have increased seed yield of coriander crop. However, the best profit is obtained when those nutrients are supplied with organic fertilizers and biofertilizers. Like inorganic fertilizers, organic fertilizers are also more profitable if added with other sources of...
nutrients. In general, growth and yield of coriander is doing better when nutrient is applied in an integrated manner (Table 2).

Table 2: The maximum seed yield of coriander obtained by different fertilizer application

<table>
<thead>
<tr>
<th>Fertilizers</th>
<th>Seed yield (kg ha⁻¹)</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>982</td>
<td>Pooja et al., 2017</td>
</tr>
<tr>
<td>Vermicompost</td>
<td>1011</td>
<td>Sanwal et al., 2017</td>
</tr>
<tr>
<td>FYM</td>
<td>1217</td>
<td>Kumar et al., 2015</td>
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<tr>
<td>BF</td>
<td>1350</td>
<td>Aishwath et al., 2012</td>
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<tr>
<td>Potassium</td>
<td>1489</td>
<td>Solanki et al., 2017</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1499</td>
<td>Sharma et al., 2016</td>
</tr>
<tr>
<td>Sulfur</td>
<td>1499</td>
<td>Solanki et al., 2017</td>
</tr>
<tr>
<td>RDF+FYM + PSB</td>
<td>1680</td>
<td>Tripathi et al., 2013</td>
</tr>
<tr>
<td>Poultry manure + RDF</td>
<td>1916</td>
<td>Dadiga et al., 2015</td>
</tr>
<tr>
<td>NPKS</td>
<td>2090</td>
<td>Yousuf et al., 2014</td>
</tr>
<tr>
<td>RDF, KNP + AZB + AZP + PSB</td>
<td>2378</td>
<td>Sahu et al., 2013</td>
</tr>
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Where, RDF – Recommended dose of fertilizers, VC – Vermicompost, FYM – Farm yard manure, PSB – Potassium solubilizing bacteria, AZB – Azotobacter, AZP - Azospirillum.

4.3 Effects on Quality Attributes of Coriander

Quality of coriander is highly responded to nutrient application. According to the study conducted to evaluate the effects of bio-fertilizers and micronutrients foliar spray, seed inoculation with azospirillum and phosphate solubilizing bacteria and foliar spray of zinc sulphate (0.5%) recorded maximum seeds per umbel, 100 seed weight, seed yield g per plant, seed yield kg per hectare, essential oils and oleoresins content (Mounika et al., 2018). Seed inoculation with azospirillum and PSB recorded maximum quality characters; essential oil content (0.89%) and oleoresins content (0.75%).

Accordingly, the combined application of biofertilizers (250 g ha⁻¹), vermicompost (5 ton ha⁻¹), and 50% NPK RDF as 30:15:15 kg ha⁻¹ is superior in registering the maximum essential oil (%) in vegetative parts of the plant at different growth stages, in dried seeds after harvest and the amount of different compounds (α-pinene, β-pinene, Linalool and Geraniol) within the essential oil (Jhariya and Jain, 2017). Therefore, INM in coriander led to best yield of quality attributes in coriander production such as essential oil, oleoresin and compounds in volatile oil.

4.4 Effect on Benefit Cost Ratio

Coriander is one of the most important economic crops (Khan et al., 2019). To obtain an excellent economic return, optimum fertilizer application has great importance. Accordingly, the study found that the use of RDF (100%) through fertilizers and combinations of different organic and inorganic sources produces the maximum grain yield, net return, and benefit cost ratio in coriander production; maximum yield (1024 kg ha⁻¹), net returns (Rs. 59556 ha⁻¹ or 24417.96 ETB) and benefit cost ratio (3.66) which is closely followed by 50 % RDF through fertilizers and 50 % RDF through vermicompost (Godara et al., 2014).

Application of different fertilizers alone leads to the lowest net profit and benefit cost ratio. However, when fertilizers are combined during application, the profit is increased. Accordingly, the maximum net profit Rs. 107689 ha⁻¹ (44152.49 ETB) and benefit: cost (2.09) is obtained in the treatment having a soil application of inorganic fertilizer (100% of RDF), bio-fertilizers; azotobacter, azospirillum and PSB (2.5 kg ha⁻¹ and farmyard manure (5 t ha⁻¹) (Jhankar et al., 2017). Similarly, it’s also reported that 60 kg N ha⁻¹ (half dose of nitrogen as basal and remaining half dose at 30 days after sowing) and 60 kg P₂O₅ ha⁻¹ (full doses of phosphorus as basal) is optimum for higher production & net returns from coriander (Javiya et al., 2017). In addition, the study also found that the application of 50% RDF, farmyard manure (5 t ha⁻¹) and PSB (2.5 kg ha⁻¹) recorded net return Rs 37280 ha⁻¹ (15284.8 ETB) and benefit cost ratio (4.38). Therefore, integrated nutrient application is very important in improving the physicochemical and biological conditions of the soils and finally helped in increasing
the net profit by maximizing benefit cost ratio (Tripathi et al., 2013; Jhankar et al., 2017; Pooja et al., 2017).

5. CONCLUSION AND RECOMMENDATION
Coriander is one of the most useful spices and medicinal plants in Ethiopia. Despite the diverse favorable agro-ecologies, germplasm availability and released opportunities; research attention given to coriander crop is very low in Ethiopia. That’s why the overall productivity and quality is low and the production system is so backward. Among several factors contributing to yield reduction, fertilizer management is of great importance.

Integrated nutrient management is very important approach for increasing coriander growth, yield and quality. In addition, it is sustainable, eco-friendly and free of contamination. Furthermore, in considering the economy, INM was found to be the most profitable in increasing benefit cost ratio by maximizing net profit.

Even though integrated nutrient management is important, there is no enough literature that clearly states the nutrient management for different crops in Ethiopia particularly for coriander. That’s why the average yield of coriander is low which might be due to weak nutrient management. Generally, INM is the best option for maximizing coriander production and productivity in which the environment is safe and sustainable. Therefore, studies have to be conducted on nutrient management practices in order to increase productivity of coriander through sustainable production system.

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7. REFERENCES


