Recent Advances in Ajwain (*Trachyspermumammi* L.) Cultivation: A Review

ABSTRACT:

Ajwain(*Trachyspermumammi* L.) also known as carom seed, belonging to the family Apiaceae which is a native from Egypt. It is a popular seed spice crop in India. It is an annual herbaceous plant bearing small egg shaped greyish brown fruits Seeds contain medicinal values specially for curing indigestion, stomach pain and elements concerning digestive system.Thymol (30-35%), γ-terpinene (23.92%), and p-cymene (22.9%) are the major constituents present in the seeds. The essential oil extracted from seeds of ajwain is being used in minor quantities in perfumery, food flavoring aspreservatives and most extensively in folk medicines, especially for remedies of stomach disorders. Dry and hot fruit fermentation is externally applied on the chest for curing asthma, and a crushed fruit paste is applied for colic pains. Evaluation and characterisation of seed spices germplasm is required for theirdocumentation and cataloguing crop wise for the further use by plant breeders and biotechnologists for improving in respect of yields, quality and resistant against biotic as well as biotic stresses. There is an urgent need for enhancing the productivity and quality of the crop by adopting suitable agronomic practices such as population densities per hectare and nutritional status of the soil. Major research is needed on pesticide residue management to earn better foreign exchange. Recent available advanced research and development have been described in this article.

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***Keywords*:** Ajwain, medicinal value, management, technologies, productivity, quality.

1. INTRODUCTION

Ajwain（*Trachyspermumammi* L.） also known as Bishop’s weed or Carom seed belongs to the family Apiaceae which is a native from Egypt. It is widely distributed and cultivated in various regions such as Iran, Persia, Egypt, Pakistan, Afghanistan and India as well as in Europe [1]. In India, it is cultivated in Madhya Pradesh,Uttar Pradesh, Gujarat, Rajasthan, Maharashtra, Bihar and West Bengal[2]. It is an erect, glabrous, or minutely pubescent, branched annual herb, 60–90 cm tall with small-sized greyish brown fruits or seed [3]. Fruits are ovoid, muricate, aromatic cremocarps that are greyish-brown; the mericarps are compressed, with distinct ridges and tubercular surface and one-seeded.Herbal treatments

have gained popularity as a dietary supplement for illness prevention and as alternative/complementary medicine in recent years[4] and essential oils are natural substance produced by plants' secondary metabolism, is used for a variety of applications [5]. Plant parts usually consumed are herb, volatile oil, and seeds. Ajwain has been shown to contain a number of phytochemicals, including alkaloids, chalcones, coumarins, flavonoids, glycosides, saponins, steroids, and tannis [6][7]. The essential oil extracted from seeds of ajwain is being used in minor quantities in perfumery, food flavoring as preservatives and most extensively in folk medicines, especially for remedies for stomach disorders [8]. Dry and hot fruit fermentation is externally applied on the chest for curing asthma, and a crushed fruit paste is applied for colic pains. The seed has proven several biological activities viz., anti-inflammatory, analgesic, anxiolytic and antispasmodic activities [9][10]. It is source of antioxidants[11] because of its preservation properties, ajwain is used in confections and beverages as whole seed, powder, and oil [12]. Thymol (35-60%) is the principal constituent of ajwain seed [13] and it also comprises γ -terpinene (23.92%), and p-cymene (22.9%) and according to the FDA's regulations (21 CFR 182.20), thymol volatile oil constituent is generally regarded as safe (GRAS) [14].

In India, it grown in an area of 38 thousand hectares with 28 thousand MT [15]. Rajasthan alone contributes about 73 percent of total ajwain production in India Anwer*et al.* , 2011 [16]. There has been increasing demand for seed spices and importing countries look at India as a consistent source. India dominates in the world seed spices trade because of their intrinsic qualities. National Agriculture Research System has contributed to providing needed technology backup and further promotion programs under Horticulture Mission have fuelled the growth [17]. it necessary to examine various plant parts are to understand their structure, function, and overall biology, single plant, flower umbel, seeds and the field view are depicted in figure 1 and figure 2 represents line sowing of ajwain crop under field conditions. The global population is continuously growing, and there is a need to produce more food to meet the rising demand. Studying recent advances in crop cultivation helps researchers develop improved farming techniques, crop varieties, and technologies that enhance productivity and increase food production to feed the growing population. This knowledge can be used to develop genetically improved crop varieties with desirable traits such as higher yield, improved nutritional content, disease resistance, drought tolerance, and enhanced post-harvest characteristics along with the development of suitable technologies to double the income of the farmers. In the present review, we delve into the latest development

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in research and development of the ajwain crop as a guide to the crop growers, breeders and the different stakeholders.

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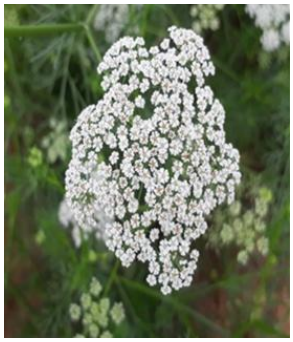

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Fig.1: Plant parts of the Ajwain,a) whole plant, b) flower and c) seeds

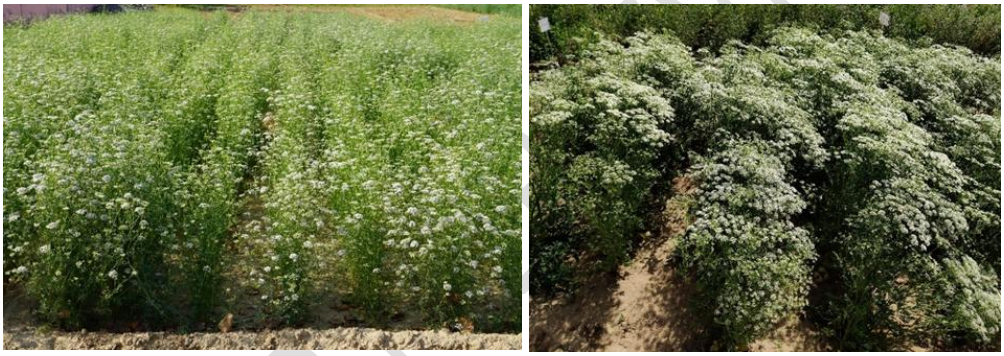

Fig. 2. Line sowing in Ajwain

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2. COMPOSITION AND USES

Ajwain contains substantial amount of moisture (8.9%), protein (15.4%) fat or ether extract (18.1%), fiber(11.9 %), carbohydrates (38.6 %) andminerals (7.1%). It also contains 2.5 to 6.0 per cent volatile oil which is yellow brownish in colour used in many ayurvedic medicines and industries of which 'thymol' is main constituent[18]. Ajwain with its characteristic aromatic smell and pungent taste is widely used as a spice in curries. Ajwain seed is an economic part which is used as spice, for flavouring numerous foods as preservatives, in medicine and for the manufacture of essential oil in perfumery [19]. Seeds contain medicinal values specially for curing indigestion, stomach pain and elements concerning digestive system Meena *et al*., 2010. It is also used in cholera, diarrhea, gastric and urinary trouble. Therapeutic uses of *Trachyspermumammi* L. seeds are stomachic, carminative, expectorant, antiseptic, acts against amoebiasis and possess antimicrobial activity. It also cures abdominal tumor, abdominal pains and piles[20].

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3. BOTANICAL DESCRIPTION

It is an annual herbaceous, cross pollinated crop bearing small egg shaped greyish brown fruits in the form of umbels. It is a profusely branched annual herb, 60-90 cm tall. Stem is striated, inflorescence compound umbel with 16 umbellets, each containing up to 16 flowers; flowers actinomorphic, white, male and bisexual; corolla 5, petals bilobed; stamens 5, alternating with the petals; ovary inferior; stigma knob-like. Fruit is aromatic, ovoid, cordate, Cremo carp with a persistent stylopodium. Leaves are pinnate, with a terminal and 7 pairs of lateral leaflets[50]. Fruitconsists of two mericarps, greyish brown, ovoid, compressed about 2 mm long and 1.7 mm wide, 5 ridges and 6 vittae in each mericarp, usually separate, 5 primary ridges [2].

4. GENETIC STUDIES AND CROP IMPROVEMENT

Evaluation and characterisation of ajwain germplasm is required for theirdocumentation for the further use by plant breeders and biotechnologists for improving in respect of yield, quality and resistant against biotic as well as abiotic stresses. Improved varieties of Ajwain available for cultivation in India were shown in table 1.Maintenance of germplasm can be achieved by prevention of out crossing with other species and redusing the effect of natural selection in an environment other than the original one. The germplasm collection available at National Research Centre on Seed Spices, Ajmer, consists of a total 92 ajwain accessions, out of which one is collected from exotic. (Annual report, NRCSS; 2016-17) [21] and 59 indigenous germplasms are availableat Jagudan, Gujarat (Priya and Mallik, 2014) [22].

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Ravindrababu *et al*.,2012[23] evaluated and reported the wide variability existed among the 43 genotypes for all the morphological and economic traits and five selections have been identified for earliness and high yield.In ajwain ample amount of variability exists for the important component traits like number of secondary branches, harvest index, number of seed umbel^{-1} and number of umbellate umbel^{-1} thus the scope of improving the crop by selection in the available variability is high. [24].

Table1: Improved varieties of Ajwain available for cultivation in India

Sl. No	Variety	Average yield (Kg/ha)	Remarks	Reference
1.	Ajmer Ajwain-1	1420	Bold seeded, essential oil 3.5%, suitable for rainfed and irrigated condition	

2.	Ajmer Ajwain -2	1280	Early maturing (145-150days). Moderately tolerate to drought. Essential oil 3.0%.	[25]
3.	Gujarat Ajwain- 1	2250	Non shattering type, late maturity (180das)	
4.	Lam Sel.-1	1000	Early maturity (145-150das)	
5.	Lam Sel.-2	1000	Spreading type, matures in 160 days.	
6.	Ajmer Ajwain-93	874.30	Early maturing (123 days), lodging resistant.	[26]
7.	Azad ajwain	1174.00	Resistant to *Sclerotinia sclerotiorum*	[27]
8.	Pant Ruchika	600-800	Suitable for both irrigated and rainfed condition. Matures in 160 DAS. Essential oil 3.4%.	[25]
9.	Rajendra Mani	-	Adopted for cultivation in Bihar	
10.	Pratap Ajwain-1	800-1000	Moderately resistant to leaf blight and powdery mildew, volatile oil 3.9%.	[28]

5. DATES OF SHOWING

Among the different agronomic practices optimum sowing time plays an important role to fully exploit the genetic potentiality of a variety as it provides optimum crop growing environment such as temperature, humidity, light etc. Sowing time is one of the most important nonmonetary input which influences the productivity of seed and oil to a great extent.

Plant height, number of primary and secondary branches per plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plantand seed yield per plantand per hawere significantly higher when the crop was sown on 30th October compared to 15th October and 14th November.The probable reason for these results might be due to suitability of climatic factors [29].Sowing of Ajwain on 1st September recorded higher yield (11.96q/ha) followed by sowing on 10th September and 20th August in Southern Telangana zone of Andhra Pradesh. Reduction in yield was observed with delay in sowing[30].

6. SPACING STUDIES

Plant spacing has an important role on growth and yield of any crop. Optimum plant density ensures the plant to grow properly with their aerial and underground parts by utilizing more solar radiation and soil nutrients [38]. Closer spacing hampers intercultural operations.

Also,in a densely populated crop, the inter-plant competition is very high for nutrients, air and light, which usually results in mutual shading, lodging and thus favours more straw yield than grain yield. On the other hand, under wider plant spacing desired population per unit area cannot be obtained, which ultimately reduces yield per unitarea. Optimum number of plants is required per unit area to utilize efficiently the available production factors such as water, nutrient, light and CO_2.

Sowing ajwain seeds at wider spacing (30 cm x 20 cm) exhibited significant differences in plant height, number of primary and secondary branchesper plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plantand seed yield per plantand per ha. Significant increase in parameters at wider spacing might be due to less competition among plants for solar energy, water, nutrients and other growth factors. The closest spacing (30 cm x 10 cm) recorded maximum seed yield; maximum seed yield (q ha^{-1}) at closer spacing is due to higher plant population[29].

Crop geometry of 50 × 25 cm resulted 10 per cent higher seed yield over 40 × 25 cm. Thus, 50 × 25 cm crop geometry is better for realizing higher yield, net return and profitability in ajwain production Mehta*et al*., 2013. Raised bedcultivation of ajwain by 75 cm raised beds with paired row planting coupled with one drip line for fertigation gave maximum seed yield of 1639.8 kg/ha [31].Muvel*et al*.,2015 [32] reported that spacing at 45 x 30 cm significantly increased theplant height, fresh weight per plant, dry weight per plant, number of umbels per plant, number of umbellets per umbel, 1000 seedweight, yield per plant, seed yield, straw yield, biological yield, leaf chlorophyll content, carotenoids content and essential oil content in seed. However closer spacing of 30 x 30 cm significantly increased the days to 50% flowering.

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7. NUTRIENT REQUIREMENT STUDIES

Crop nutrient management techniques include chemical fertilisation, organic manuring, and mixtures of both inorganic and organic fertilisers[4] which are in combination improve soil health and ecosystem sustainability. Ajwain is a seed spice crop not only its yield but also its quality is important and both can be achieved only by maintaining soil fertility through proper nutrient management practices. The level of nutrient supply at which the maximum yield of the plant is obtained reflects the optimum requirement of a particular plant species. The fertility and productivity of the soil cannot be maintained solely by the application of inorganic fertilisers. Restoration of soil health may also be aided by the incorporation of organic sources such as FYM and biofertilizer[33]. Further, increase in

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nutrient supply does not affect plant growth but reflects the luxury consumption without significantly contributing to either yield or quality.

Asangi*et al*., 2023[34] studied that, out of varying levels of nitrogen, i**.**e**.** 0, 30, 60, and 90 kg N per ha**.** Maximum biomass was recorded at 60 kg N per ha, whereas maximum seed yield was recorded at 60 and 90 kg N per ha**.** The experiment plot received 60 kg N ha^{-1} exhibited maximum values for plant height, number of primary and secondary branches per plant, plant spread, stem diameter, number of umbels per plant, number of umbellets per umbel, number of seeds per plantand seed yield per plantand per ha. Higher doses of nitrogen whichenhanced protein and chlorophyll synthesisleading to marked improvement in vegetativegrowth of the plant as well as yield and yieldattributes of the crop [29].

Significantly higher yield attributes *viz*., umbel per plant (184.32), seeds per umbellates(16.97), umbellates per umbel (17.64), test weight (2.01 g) seed yield (11.69 qha^{-1}), net return of Rs. 20320 per ha and BCR (0.97) in ajwain were obtained with application of 50 +25 kg N and P_2O_5 /ha. Mehta *et al*., 2013.Vahidipour*et al*.,2013 [51] studied the effects of nitrogen on growth and yield traits in ajwain**.** The highest grain yield was related to consumption of 200 kg N per ha**.** Further, Essential oil yield increased significantly with increasing nitrogen**.** The levels of fertilizers did not affect significantly the fresh weight per plant **(**g**)** at 90 DAS and harvest index **(%).** The maximum benefit**:** cost ratio **(**2**.**05**:**1**)** was found 60**:**30**:**30 kg NPK per ha [32].

Among the various levels of fertilizer tried, the 60:30:30 kg NPK per ha. significantly increased the growth, yield and quality attributes of ajwain under Mandsur condition [32]. Out of different nutrient levels, 80; 40;40 kg NPK per ha. should form the integral part of ajwain and package of practices for getting a good harvest of the ajwain crop under climatic conditions of Vidharbha region of Karnataka[49]. Application of nitrogen up to 60 kg/ha recorded significantly increased plant height, dry matter accumulation and chlorophyll content and number of umbels per plant (181.0), number of seeds per umbel (207.9) and seed (1081 kg ha^{-1}), straw (3012 kg ha^{-1}) and biological yields (4093 kg/ha) of ajwain over preceding levels but remained at par with 90 kg N per ha [35]

8. IRRIGATION STUDIES

Water is very precious and scarce input and its efficient utilization is quite necessary. Efficient use of irrigation water aims at the utilization of available water resources to the maximum possible advantages in the crop production. As such use of this costly and scarce

input through efficient water management practices is very essential. Among the several recognized criteria of irrigation scheduling the climatological approach (IW/CPE ratio) is very useful. Evapo-transpiration by a full crop cover is closely associated with the evaporation from an open pan [36]. Information on optimum water requirement of ajwain is available meagre which calls for a need to generate more information on the combined effect differentirrigation scheduling based on IW/CPE ratio for greater yields in ajwain.

Application of irrigation at 18 days interval gave higher yield attributes viz. Umbel per plant (184.32), seeds per umbellates(16.97), umbellates per umbel (17.64), test weight (2.01 g) seed yield (11.69 qha^{-1}) over irrigation at 15- and 12-days interval [37]. Out of 2 irrigation methods i.e. Gyro net (micro sprinkler) and mega net (mini sprinkler), mega-net was performed better and gave 13.4% higher seed yield in ajwainthan the gyro net micro sprinklers [38, 39].

9. WEED MANAGEMENT STUDIES

Weed control is the segment of weed science that most people are familiar with and where the greater part of education and training is focused. The methods employed to manage weeds vary, depending on the situation, available research information, tools, economics, and experience. Improved agricultural technology over the centuries has contributed greatly to increased food production Raghuwanshi et al., 2023 [48]and a related increase in our standard of living. Excessive weed populations reduce availability of water and nutrients to the crop. Sound agronomy and crop management throughout the growing season, in addition to the use of effective herbicides at the correct time, are critical to achieve optimumyieldand high oil quality. It has identified that 69 days after sowing is the Critical time for weed competition in ajwain crop [40]. Advances in weed control practices have been an important part of these gains. Some of the recent advances on weed management in ajwain have been discussed here;Meena*et al.*,2015[41] The pre-emergence application of oxadiargyl @75 g per ha + one hand weeding at 45 days after sowing (DAS) and pendimethalin at 1 kg per ha + one hand weeding at 45 DAS recorded significantly higher plant height, number of primary, secondary branches, number of leaves, number of nodes and dry matter accumulation per plantat (60 DAS, 90 DAS and at harvest). Hand weeding at 20, 40 and 60 DAS recorded significantly higher plant height and dry matter productionof the crop, yield attributes and yieldover the other treatments. Further, among integrated weed control treatments, oxyfluorfen @ 0.12 kg a.i per ha as PE fb quizalfoppethyl @ 0.05 kg a.i per ha as PoE at 20

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DAS proved efficient in recording higher weed control efficiency (72.68%), seed (1,019 kg ha^{-1}) and haulm (1,222 kg ha^{-1}) yields with better weed index (11.77) Nalini *et al*.,2017 [47]. Further, application of Oxadiargyl 50 g a.i. ha^{-1} and pendimethalin 1 kg a.i ha^{-1} applications led to lower weed instensity and increased weed control efficiency (WCE) respectively and seed yield in the weed-free plots were statistically comparable to the yields from the application of oxadiargyl 50 g a.i. ha^{-1}[42].

10. INTERCROPPING STUDIES

Higher economic returns per unit area, better solar and land utilization, maintenance of soil fertility, fulfilling the supplementary requirement of the farmers, safety against natural calamities and conservation of soil moisture are the targets or goals of intercropping or mixed cropping in any farming system**.** Since the area available for agriculture is limited and the demand for food has been increasing considerably, replacement of traditional crops by seed spices may become unsustainable in the long run due to reduction in area for cultivation of food and other commercial crops, unrealistic price, fluctuation in demand, supply, long gestation period in certain spice crops etc. Therefore, it is necessary to explore the possibilities of growing seed spices in areas where traditional agriculture is uneconomical or unsustainable. Mirhashemi*et al*.,2009 [43] reported that the harvest index and dry weight per plant in ajwain was highest in intercropping compared to pure culture. The highest land equivalent ratio (1.47) was obtained in single row intercropping and the lowest (1.28) in double row intercropping.

11. PEST

During storage, food grains and products are severely destroyed by insects and other pests. Stored spices are infested by two predominant pests *viz.*, cigarette beetle (*Lasiodermserricorne*) and drugstore beetle (*Stegobiumpaniceum*) besides numerous minor pest like, Khapra beetle, Lesser grain borer (Rajendran 2003). Among non-chemical method for managing drug store beetle population in ajwain seed, diatomeous earth @ 0.2% showed maximum mortality of bettle, minimum damage to seeds and low microbial loads. Interestingly, impregnation of 1.0% w/v own seed oil on ajwain seed resulted maximum protection against beetle population. [39]**.** Modified Atmospheric Packaging (MAP) was found highly effective for management of beetle population in cumin and ajwain seeds using different inert gases[44].

12. DISEASE MANAGEMENT

The crop suffers due to diseases influencing the yield negatively. It is essential to manage the pathogen causing diseases and also to produce pathogen free high-quality seed[45].The available recent advances on disease management in ajwain crop hascited in table 2.

Table 2: Diseases and their management in Ajwain

Sl. No.	Disease	Symptoms	Management	Reference
1	Alternaria blight (*Alternaria alternata*)	Typical leaf spot symptoms appear first and later develop blight symptoms. The spots are small irregular, reddish brown with tan to gray in centre.	Mancozeb 0.25% is the best as spray to control the disease.	
2	Collar rot (*Sclerotium rolfsii*)	The stem near the soil gets infected and lesion is formed. The white hyphae grow around the stem which later covers the lower portion of the stem. Mustard like sclerotia are formed by hyphae. The leaves exhibit yellowing starting from the base. The plant dries up.	The disease develops in patches. Turning of soil helps in checking the disease spread.	[45].
3	Powdery mildew (*Eryiphepolygoni*)	All the above ground parts are infected which get covered by white powdery mass the conidia of the fungus. When the inflorescence gets infected all the flowers get aborted with no seed formation.	Spray of wettable sulphur 0.25% or Karathane 0.05% is effective in controlling the disease.	

First report of phytoplasma infection affecting Ajwain in India, was observed in Lucknow. The symptoms included small chlorotic leaves, highly proliferating shoots, witches broom appearance, shortened internodes and an overall stunted growth. Poor flower heads and fruit setting caused considerable yield losses for farmers[46].

13. ECONOMICS

In view of the rapid spread of technology in agriculture, farmers are required to face a severe competition, particularly when the farm produce is to be exported. One of the ways to survive in the competition as also to gain better profit is to have a lower cost of production. For this farm costing or working out the cost of production of crops/enterprises, is necessary.

The farm costing is also useful to the formers to keep watch on the expenditure which is increasing in the modern farming. Significantly higher yield attributes, net return (Rs. 20320) per ha and BCR (0.97) in ajwain were obtained with application of 75 kg N and 50 kg P_2O_5per ha.

The maximum net return (Rs. 35692) per ha was recorded with the spacing (45 x 30 cm). Similarly, significantly maximum net returns (Rs. 29249) per ha was recorded with 80:40:40 NPKfertilizer application per ha. The highest B:C ratio (1.92:1) was recorded with spacing 45 x 30 cm. Muvel*et al.*,2015Nalini*et al.,* 2017[32] [47]reported m aximum net returns (Rs. 67692 per ha) and highest cost: benefit ratio (1:2.7) was obtained in oxyfluorfen @ 0.12 kg a.i ha-1 as PE fb quizalfop-p-ethyl @ 0.05 kg a.i per ha as PoE at 20 DAS.

14. CONCLUSION:

Looking into importance of this crop there is an urgent need for enhancing the productivity and quality of the crop. Biotechnological interventions are very much required to understand the crops genomics and for developing desirable varieties for future. Focused work on quality analysis and value addition is required looking to the high medicinal value of this crop and good agricultural practices standards for organic and non-organic cultivation. Major research is needed on pesticide residue management to earn better foreign exchange.

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